From Pain to Laughter: how the body expresses what we feel

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EMO & PAIN REHABILITATION

WWW.EMO-PAIN.AC.UK

Technology for Chronic pain rehabilitation

UCL · Imperial College London · University of Leicester · EPSRC · The National Hospital for Neurology and Neurosurgery · pamela

CHRONIC PAIN| What it is

- Chronic pain is defined by lasting >3 months, and/or continuing despite healing and/or treatment.
  - Due to changes of the central and peripheral nervous system resTuling in amplification of pain signals
  - overactivity in pain pathways at multiple levels from the periphery to the brain, and underactivity in descending pathways that modify pain signals (Tracey & Bushnell, 2009)

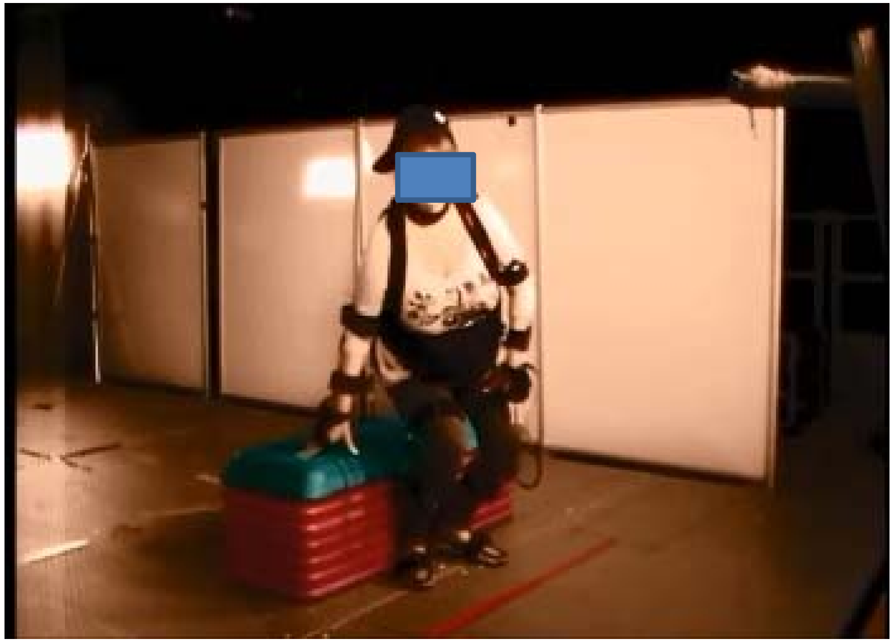
- Some results from illnesses (e.g. diabetes), some from treatment (e.g. chemotherapy), some from injuries, and some has no clear reason.
  - If the cause cannot be fixed, and the pain does not resolve with treatment, then healthcare focuses on rehabilitation despite continuing pain.

- Chronic Pain impacts work, social/family life, sleep, mood, and identity.
  - 1 in 7 of the population in Industrialized countries
  - Up to 20% of people with chronic pain are depressed at some time
  - Up to 25% have lost their jobs

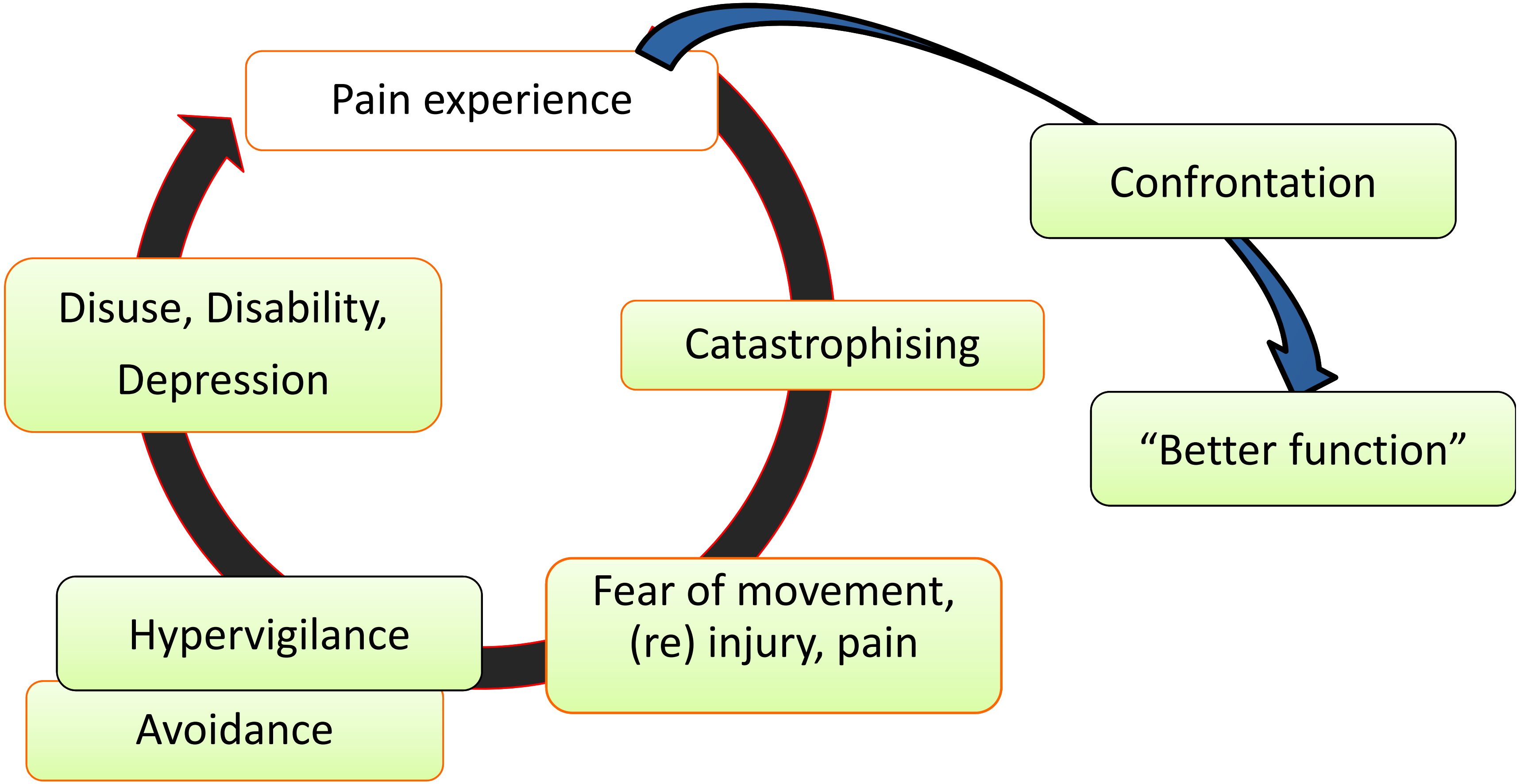
CHRONIC PAIN | Physical Rehabilitation

- Physical activity
  - Help maintain physical capabilities and
  - confidence in movement
  - Reduce spread of pain

- Emotions as a barrier to physical activity
  - Wrong beliefs about meaning of pain
  - Fear of injury or increased pain
  - Negative emotions increase sensitivity to pain

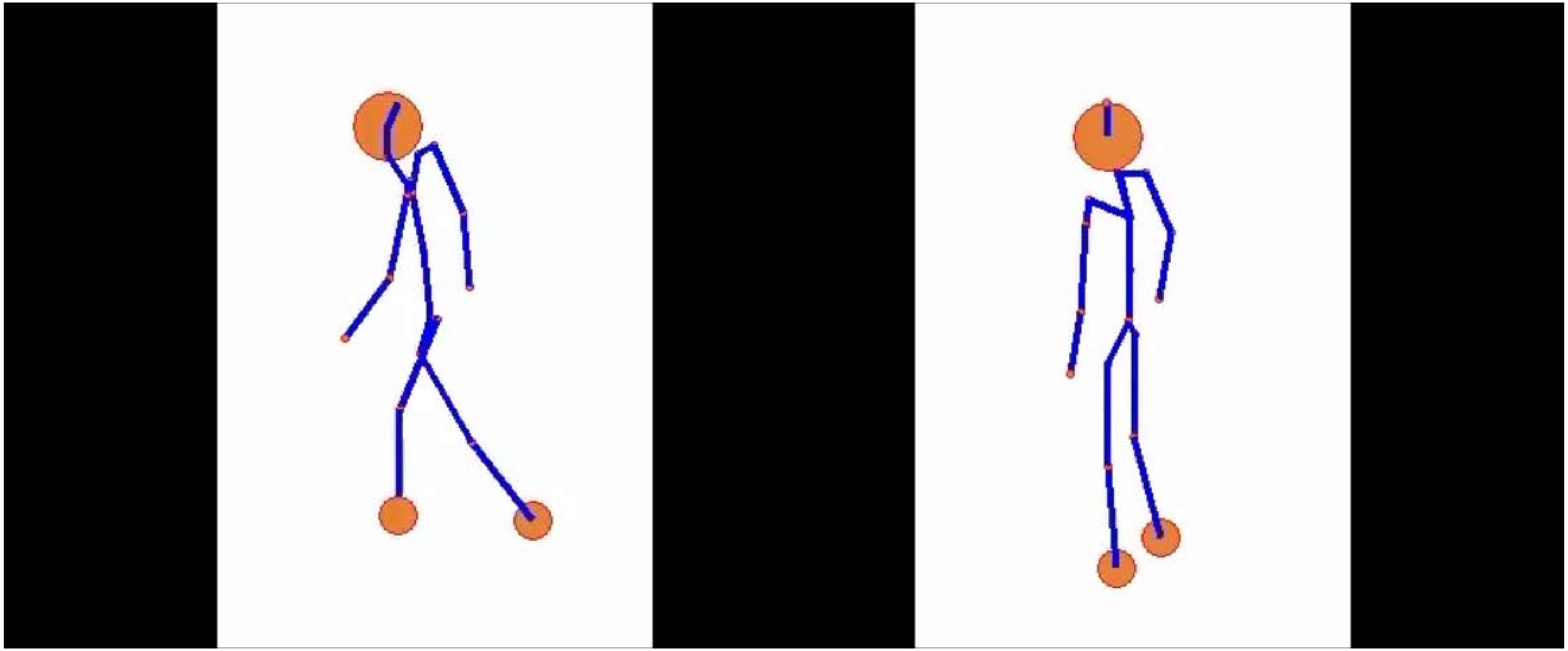


CHRONIC PAIN| Fear Avoidance Model



Adapted from Vlaeyen et al, 2000

EMO&PAIN| A communicative language



N. Kleinsmith A, Bianchi-Berthouze N. "Affective Body Expression Perception and Recognition: A Survey", *IEEE Trans. on Affective Computing*, 4(1): 15-33, 2012.

CHRONIC PAIN | A communicative language

- People with chronic pain exhibit communicative and protective behaviour (Sullivan et al., 2006)
  - Facial expressions such as grimacing communicate with or without intention the presence of pain
  - Body behaviour: protect one's body from injury or pain increase but has also to communicate their state and fear to other (e.g., fear of injury).

- Pain-related behaviours in chronic pain is at best weakly correlated with the intensity of pain or seriousness of the condition (Teske et al., 1983)

BODY BEHAVIOUR | Social isolation

- Protective behaviour used to evaluate personality traits (Martel et al, 2012; Ashton-James et al., submission)

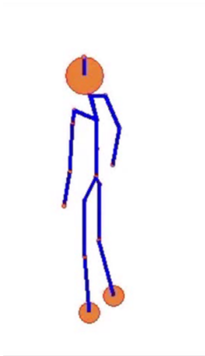
- People showing pain-related behaviour are considered
  - less ready to work, less competent
  - less likable
  - less dependable
  - Less warm

  than people not exhibiting any pain-related behaviour.

- Protective behaviour less likable and dependable than communicative behaviour

BODY BEHAVIOUR | Lack of awareness

- People are not necessarily aware of their non-verbal behaviour.
  - Automaticity
  - Dysfunction of the proprioception system
  - Avoid looking at video or mirror



- Many patients showed surprise on seeing their body movement replayed by an avatar.
  - meticulously observing of their avatar
  - noticing protective behaviour and keen to understand it.

EMO&PAIN Project| Goal 1

- To develop technology to support people with chronic pain remaining physically activity:
  - Sense and track people behaviour
  - Increase awareness of one’s behaviour
  - Provide personalized support
  - Adapt activity plan on the fly

STUDY 1 | Understanding people with CP

- Qualitative studies to understand needs, barriers, strategies:
  - Interviews with 14 CP patients
  - 7 Blogs and 18 Forums for Chronic Pain (25 CP patients)
  - Pain management class observations followed by video-cued interviews
    - 3 physiotherapist-led groups or gym exercise sessions (12 CP patients)
    - 2 pain management introduction sessions (15 CP patients)

DESIGN| Strategies to facilitate physical rehabilitation

Developing positive awareness of movement

Augmenting pleasurable sensations

Go with the flow

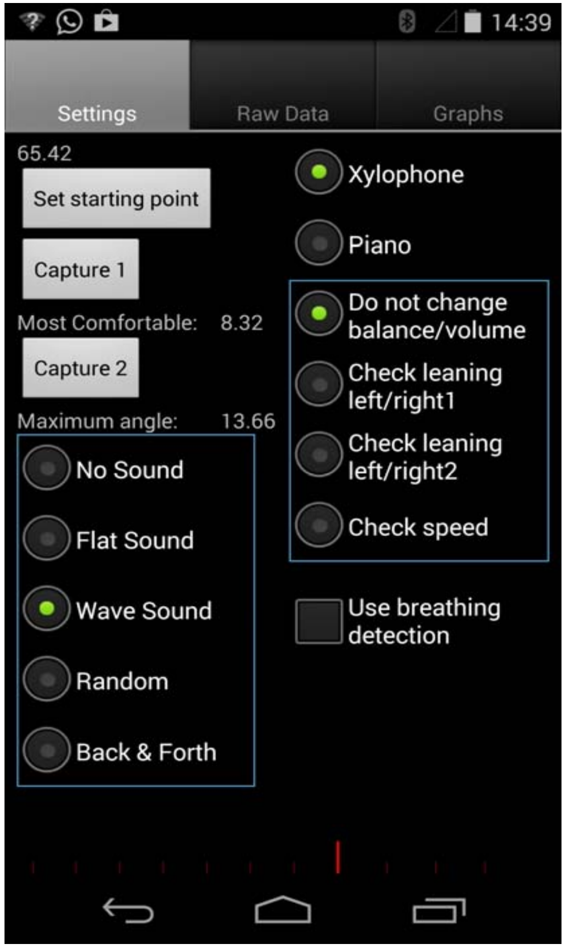
Reducing negative emotions

Taking control of rehabilitation

Singh, et al. Motivating People with Chronic Pain to do Physical Activity: Opportunities for Technology Design. Proc *CHI '14,*

DESIGN | Sonification of movement

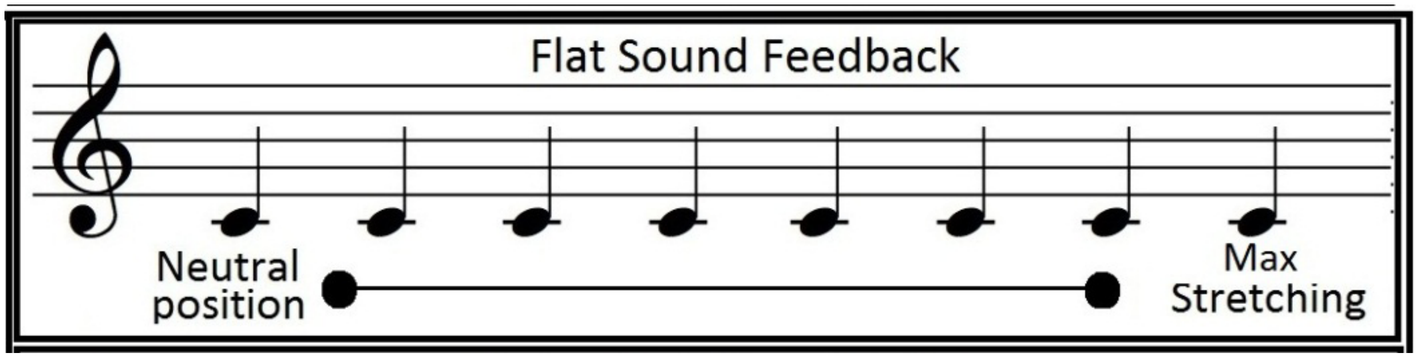
Smartphone



Smartphone
Movement sensor

SONIFICATION FRAMEWORK| Sense of control

- Sonification not new in physiotherapy & sports:
  - facilitate attention, learning, motor initiation
- But our aim: to use it to address psychological needs
  - Sense of control, confidence, self-efficacy
  - Anchor the sound to specific body psychological barriers



Simple exercise Space

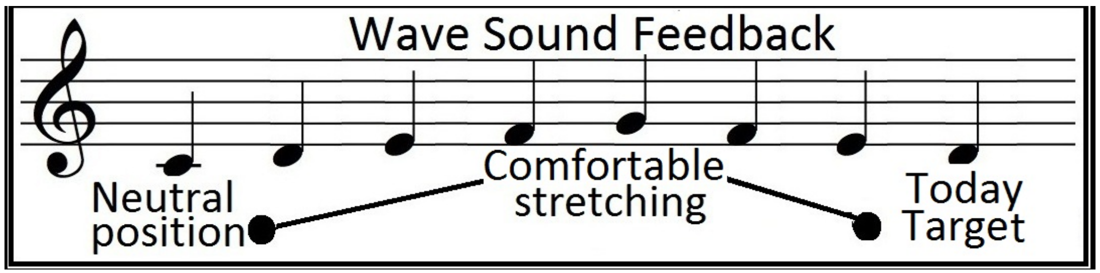
EMO & PAIN
REHABILITATION

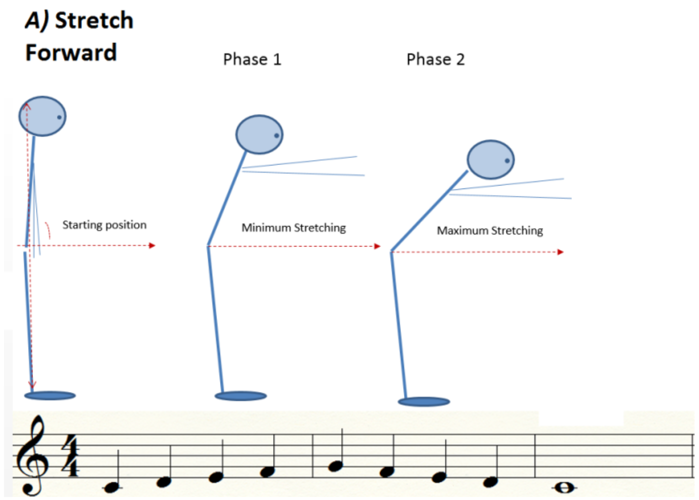
EPSRC

Singh, et al. Motivating People with Chronic Pain to do Physical Activity: Opportunities for Technology Design. Proc *CHI '14,*

SONIFICATION FRAMEWORK| Elements

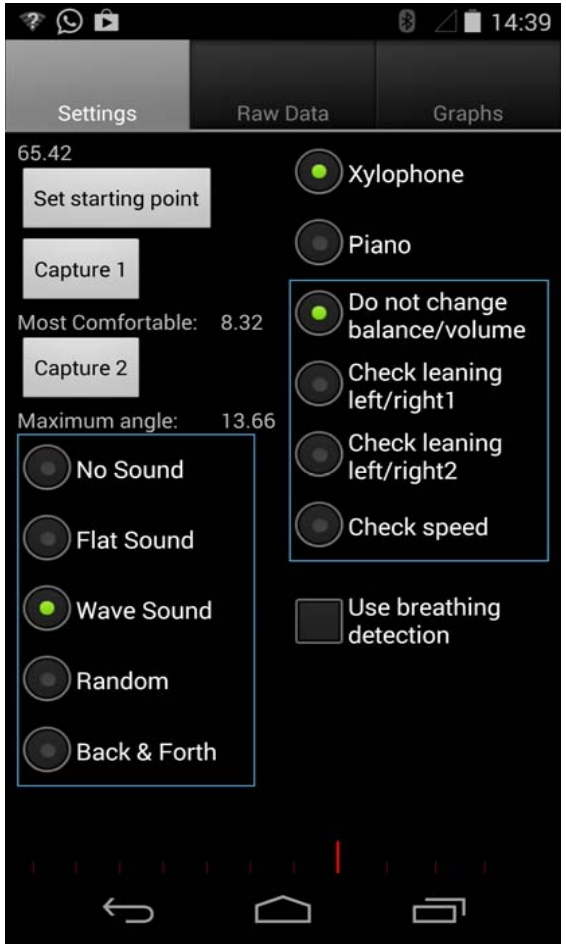
- **Simple tone:** enhance movement awareness and simple to understand (Principle 1)
- **Sonic phrase:** a set of correlated sonic events characterized by variations of one or more sonic features (Principle 2).
- **Shape & Combination of phrases:** Endings of phrases, changing between phrases, or other clearly emerging sounds can be used to mark milestones (Principle 3, Principle 4)





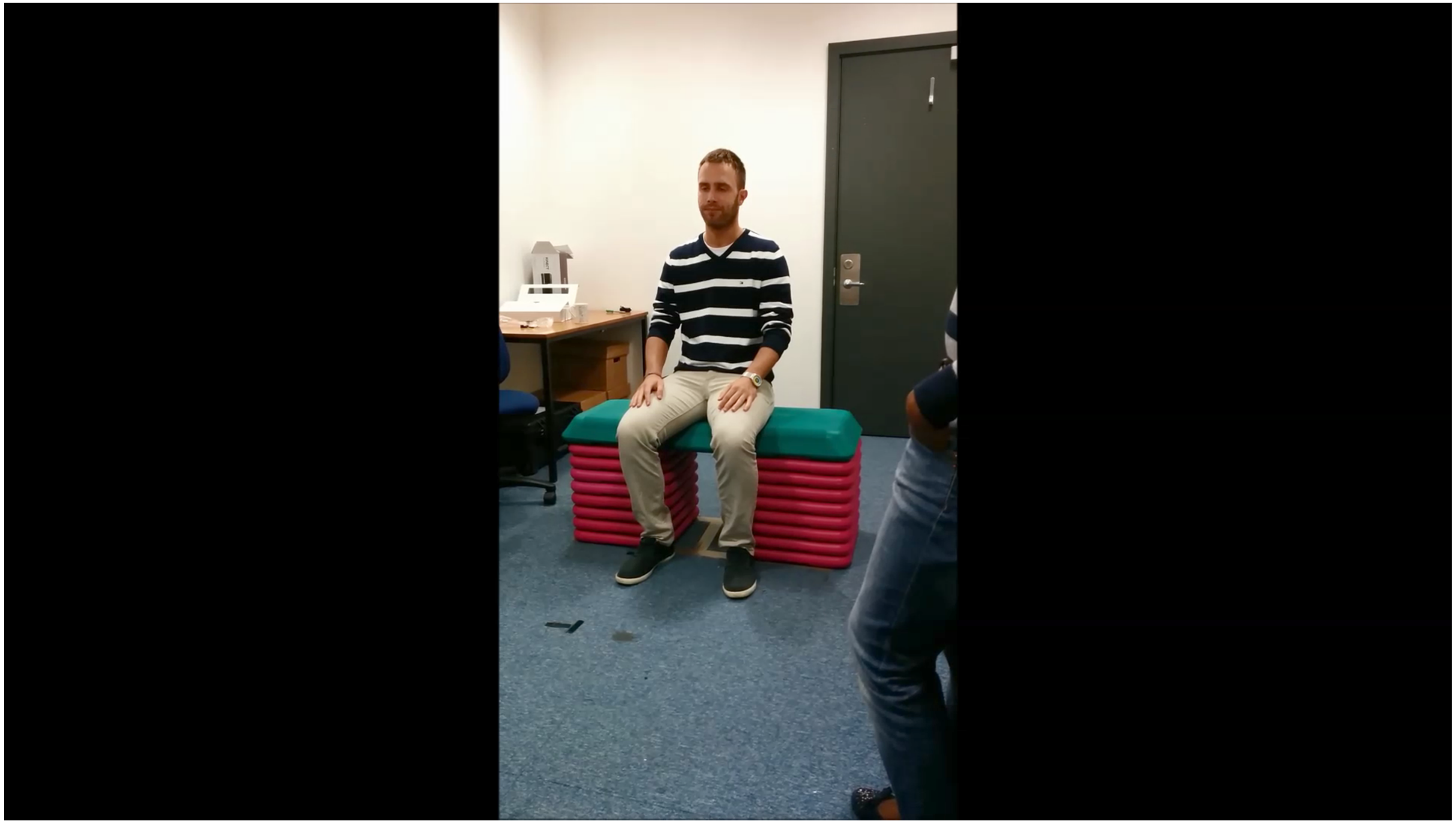
FRAMEWORK| Breathing

Smartphone



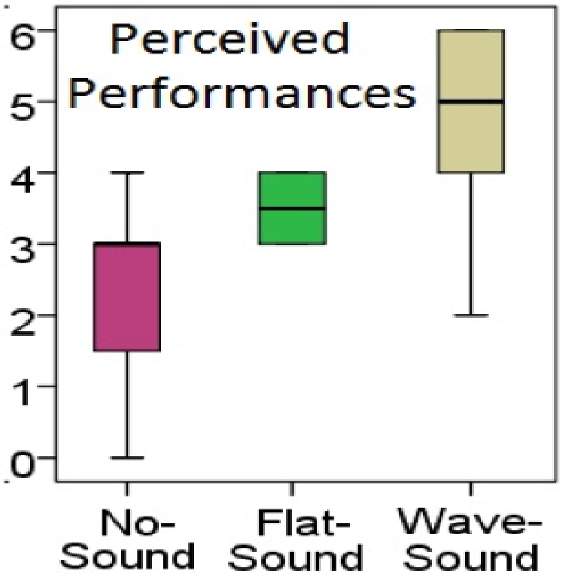
Movement & Breathing sensors

TECHNOLOGY (1)| Informing of avoidance strategies



In Collaboration with InfoMusic, University of Genova (Prof. Camurri)

TECHNOLOGY (1)| Results

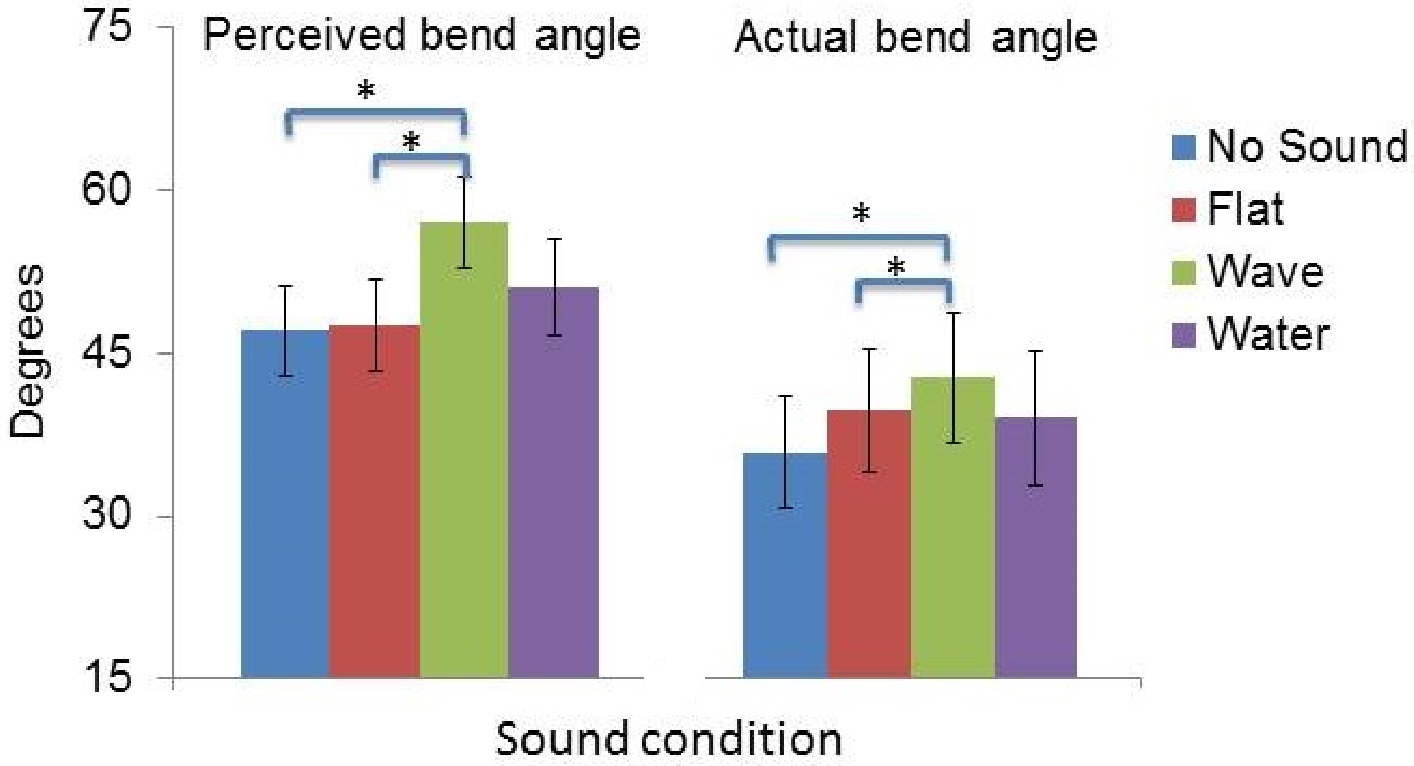


"With the shape sound, it seems like I was climbing a mountain ….. After passing the top position, I would know that I have passed a certain level and it just encouraged me that I might be able to do a bit more than that.

But without the sound, you have no idea [where you are]". (PCP2).

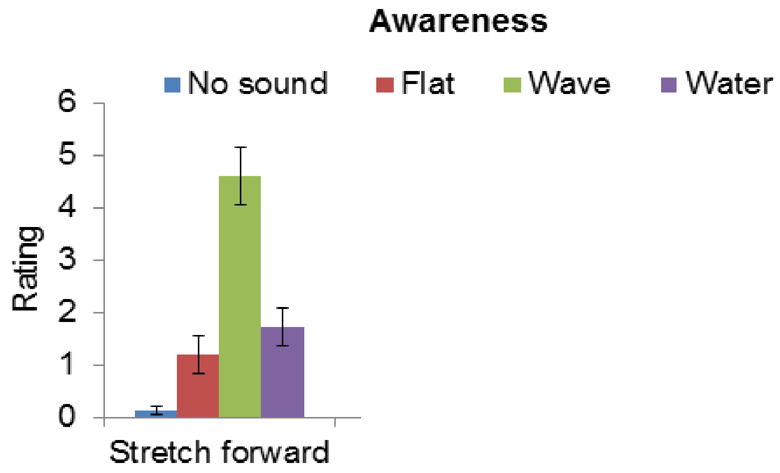
"to focus on something other than what you are doing. With the up and down sound, I can hear more clearly how I am doing."

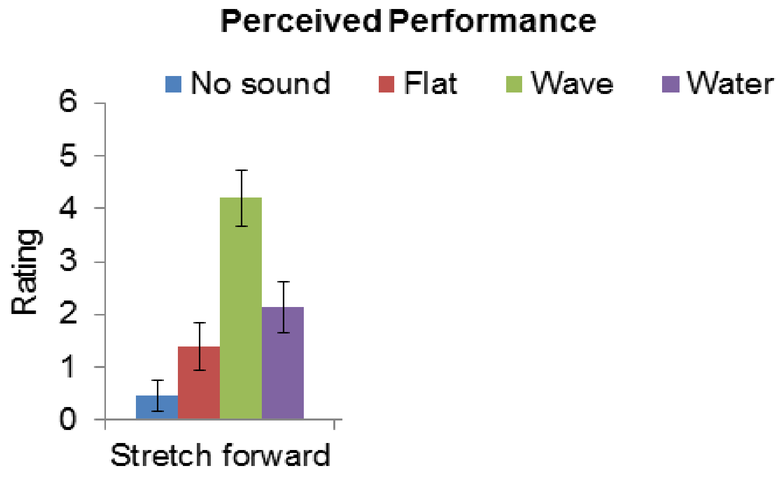
RESULTS| Self-report and behaviour

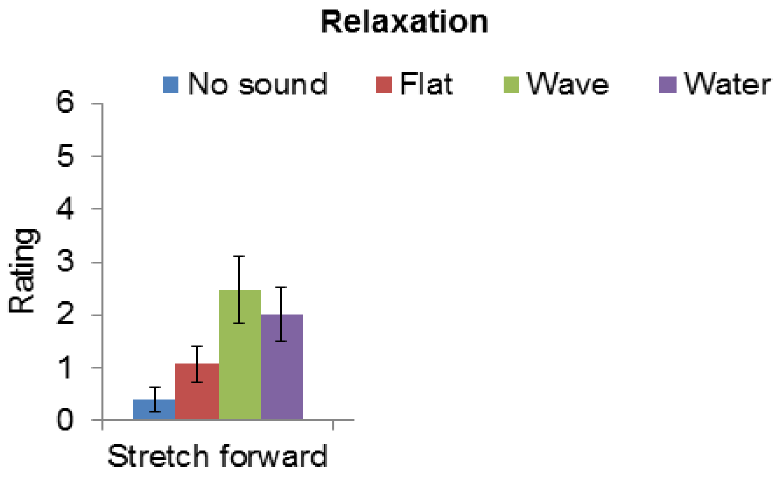


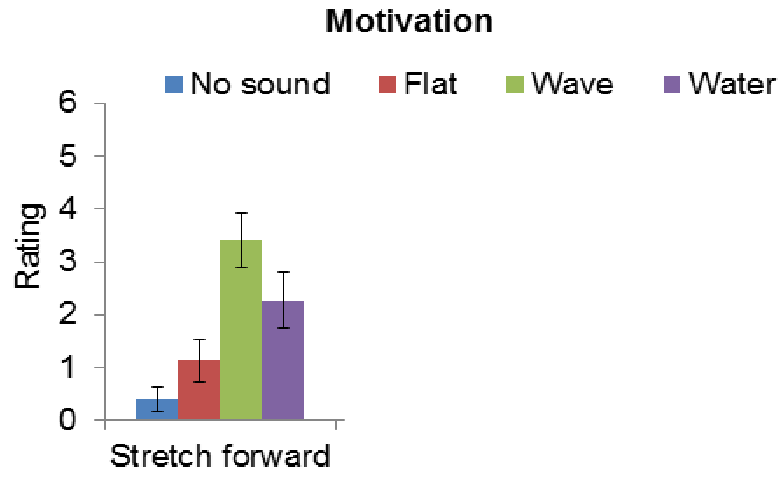
Singh et al. "Go-with-the-flow: Tracking, Analysis and Sonification of Movement and Breathing to Build Confidence in Activity Despite Chronic Pain", *Human-Computer Interaction, (in press)*

RESULTS| Self-report and behaviour









INTERVIEWS| Home studies & Focus Group

“I will in the kitchen put things a bit higher that I find hard to reach. So I have to ... you know it makes you. It's frustrating but it makes you stretch a bit far and I use little things like that.”

INTERVIEWS| Reducing hypervigilance

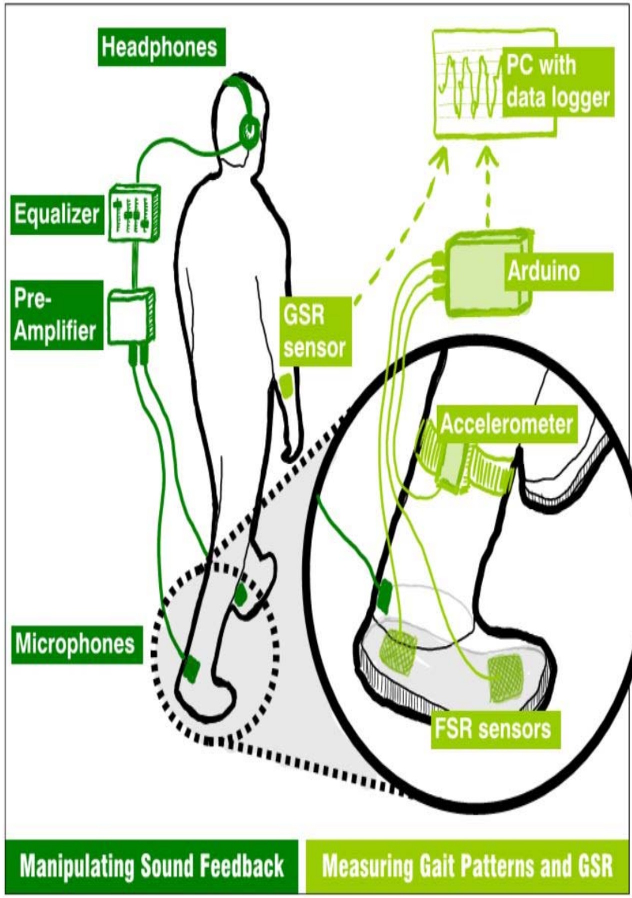
“my proprioception is poor with my back because of fear. And even though the fear is very real, it’s not even a conscious fear; it’s something that’s definitely ever-present. And something like this would tell me, tell my intellect to overcome my fear, because you’ve got this far, you can go again.”

Sense of Body and the Sensing Body

The sense of our physical body is crucial for our **interaction** with our environment, being tightly linked to **action-awareness** and **self-esteem**

This sense of body is acquired through **sensing** and **acting**

ALTERING BODY PERCEPTION| Sensing & Sonifying Shoes

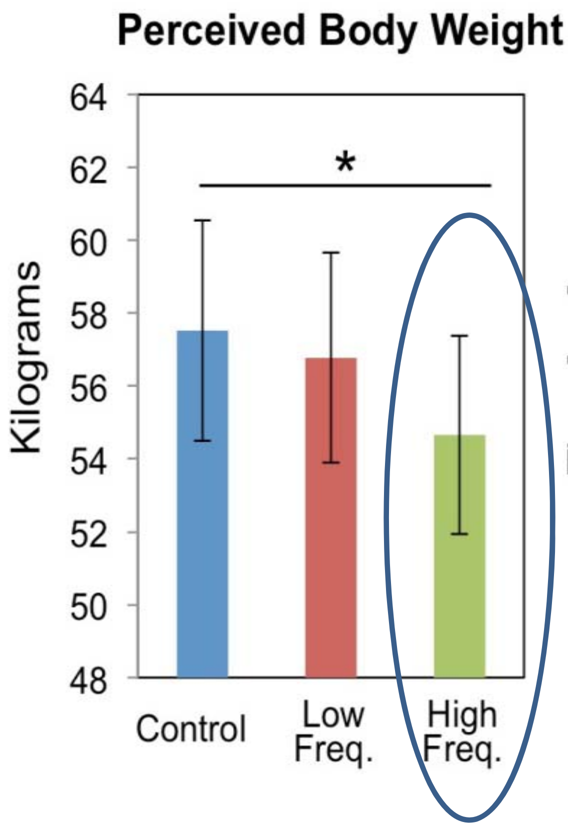


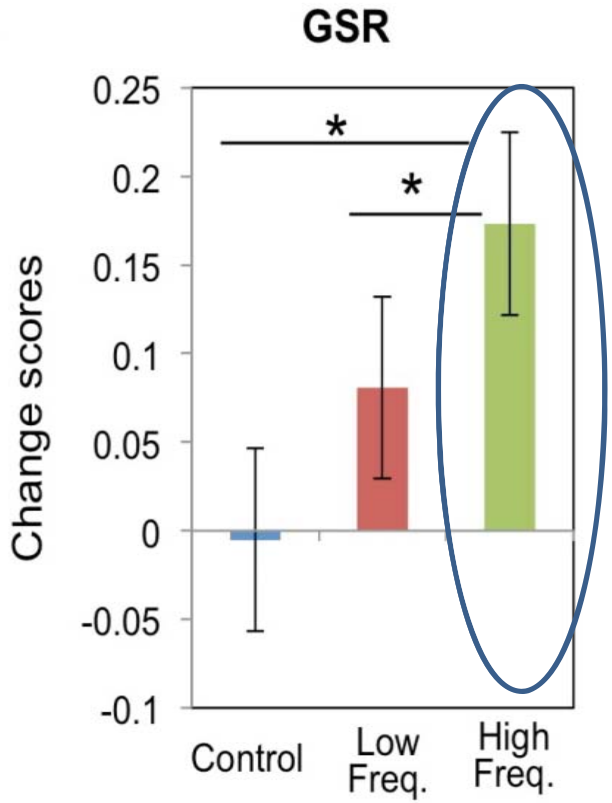
<u>The Hearing Body Project (led by **Ana Tajadura Jimenez**) (CHI'15}</u>

In collaboration with Nic Marquardt and the Centre for the Study of the Senses (O. Deroy)

Ana Tajadura-Jiménez
ESRC – Future research Leader: 2012-2015

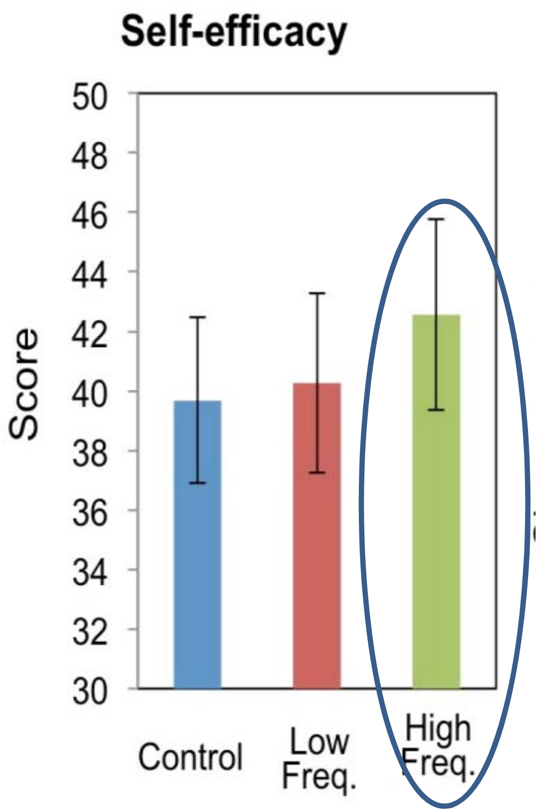
THE MAGIC SHOES | Results on altered body perception

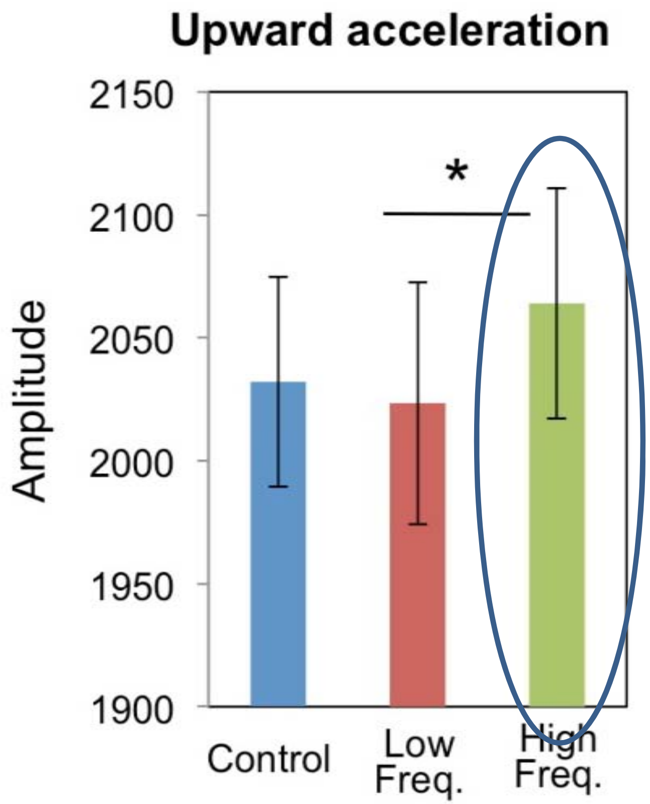




Tajadura-jimenez, et al. (2015) As Light as your Footsteps: Altering Walking Sounds to Change Perceived Body Weight, Emotional State and Gait, CHI'15

THE MAGIC SHOES | Results on altered body perception





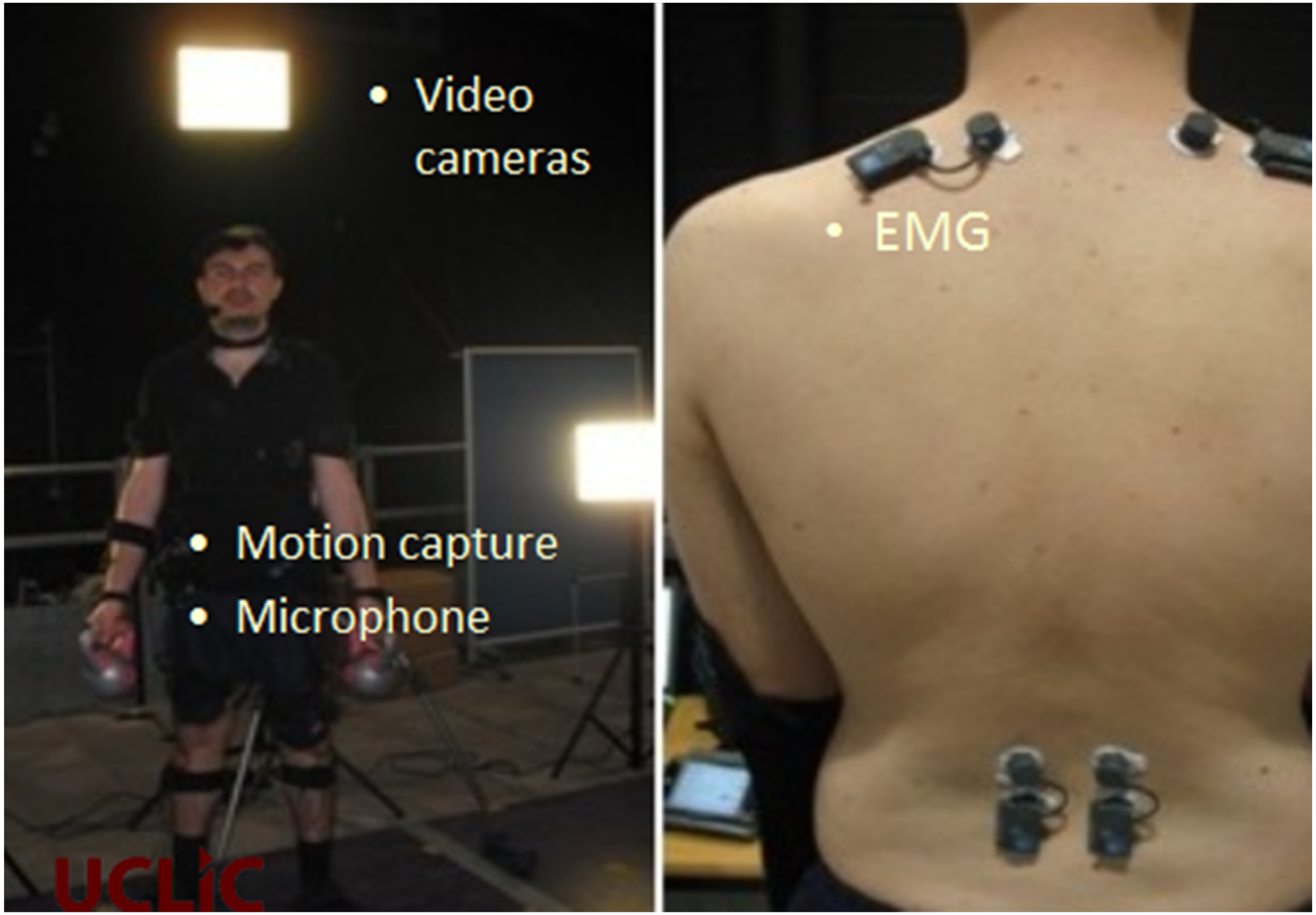
Tajadura-jimenez, et al. (2015) As Light as your Footsteps: Altering Walking Sounds to Change Perceived Body Weight, Emotional State and Gait, CHI'15

EMO&PAIN Project| Goal 2

- To develop technology to support people with chronic pain remaining physically activity:
  - Sense and track people behaviour
  - Increase awareness of one's behaviour
  - Provide personalized support
  - Adapt activity plan on the fly

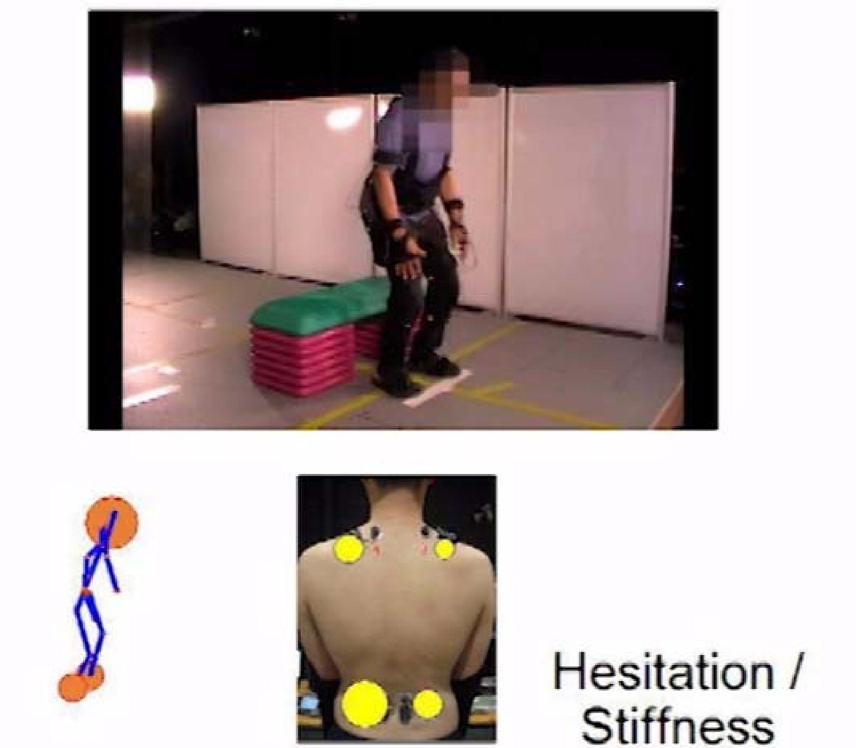
  - Personalization needs Automatic detection of pain and anxiety

EMO&PAIN| Automatic detection of pain-related emotions



UCLIC

SENSING PAIN BEHAVIOUR| Data Collection (open to the community ~ June'15)

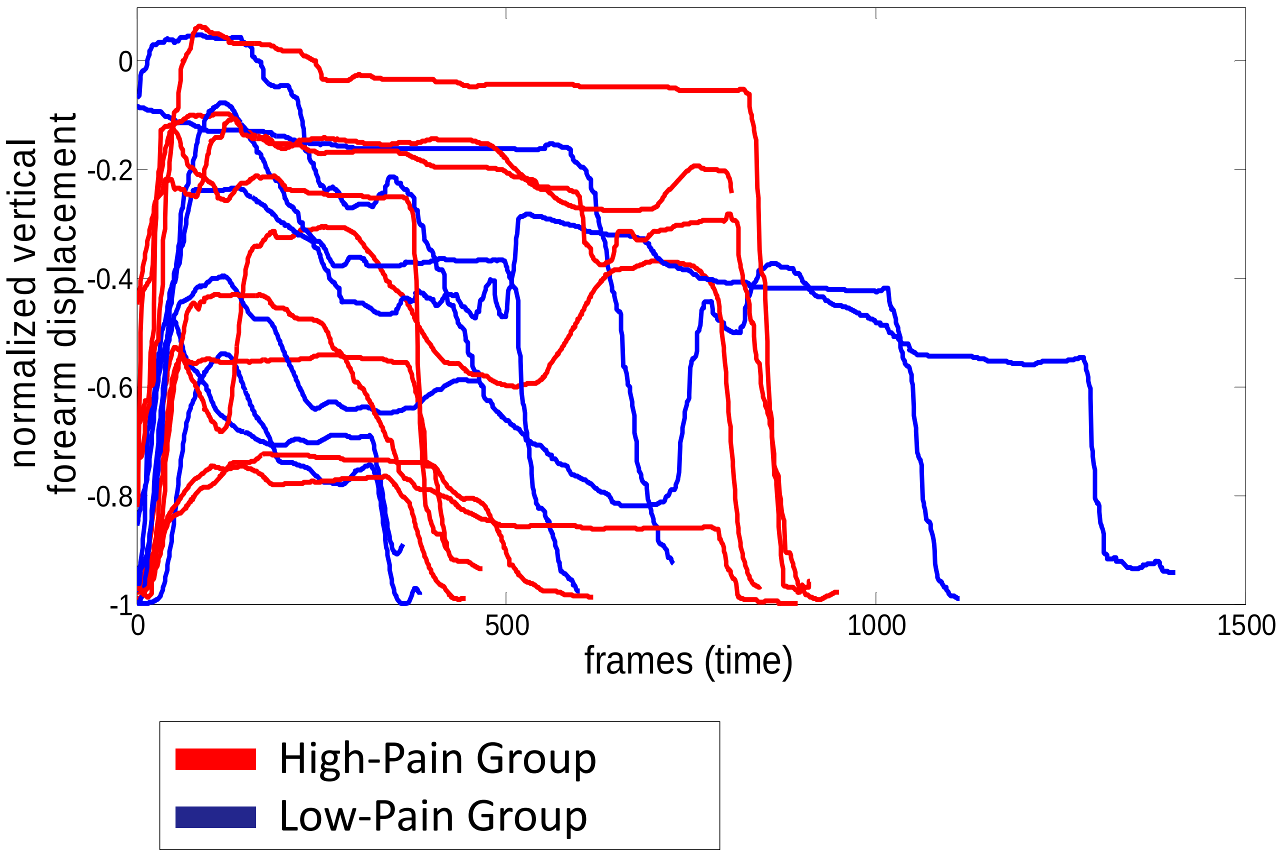


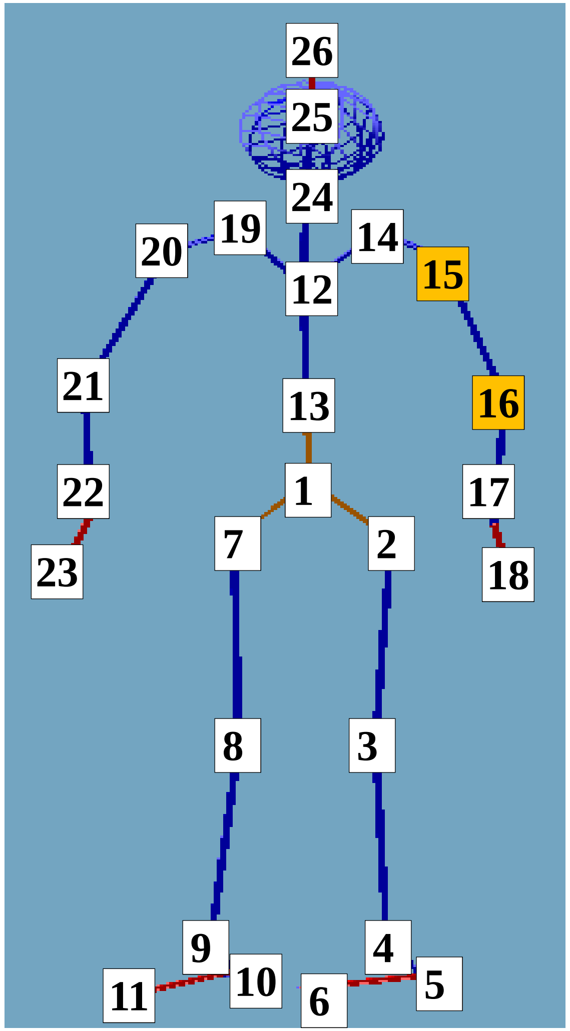
Aung, M. S. H., et al . (2015). Automatic Recognition of Fear-Avoidance Behaviour in Chronic Pain Physical Rehabilitation. *IEEE Transactions on Affective Computing*

UCL Imperial College London University of Leicester EPSRC pamela

PAIN LEVEL| Feature selection for stretching and flexion

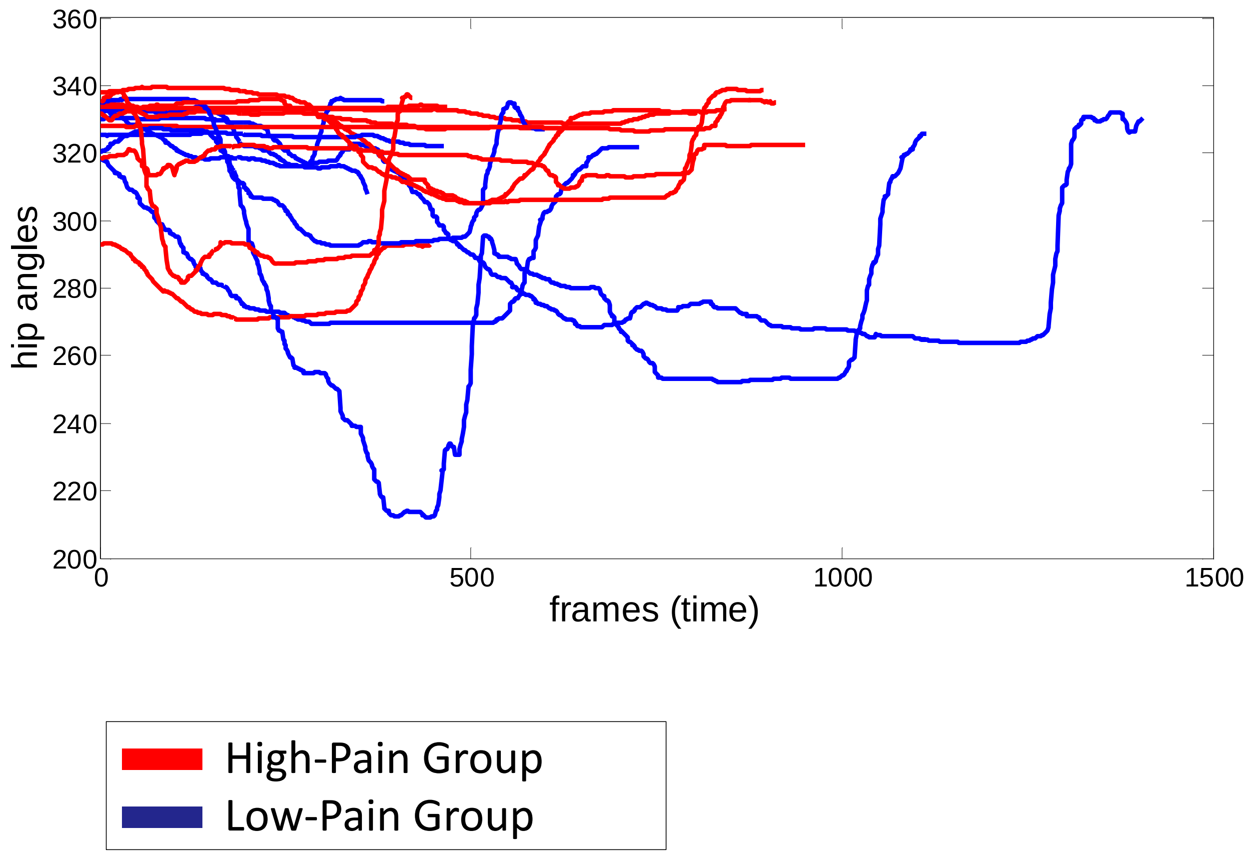
Arm steadiness in vertical axis

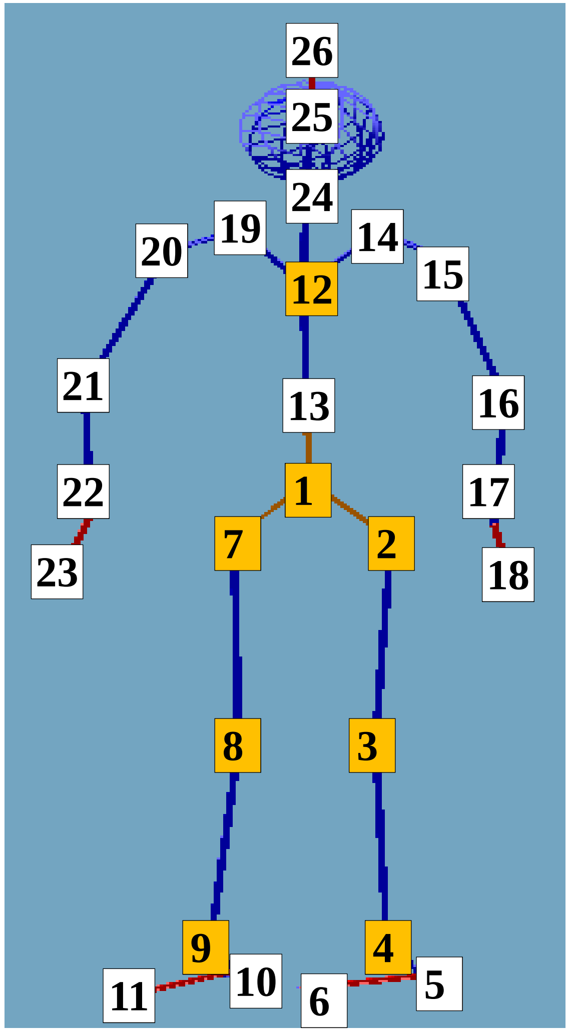




PAIN LEVEL| Feature selection for stretching and flexion

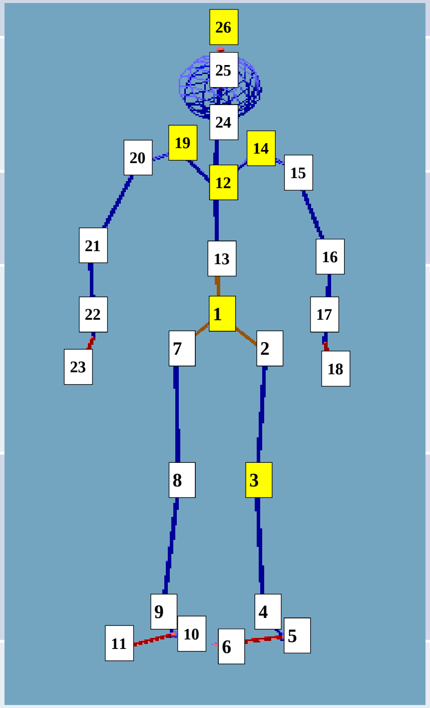
Amount of trunk flexion





PAIN LEVEL| Feature selection: Stretching & Flexion

Body Part	Kinematic Features
Crown	Movement of the crown (-26-) relative to the spine (-12-) in the forward-facing direction
	Vertical displacement of the crown (-26-)
Legs	Vertical motion of the left knee (-3-)
Spine	Acute angle at the spine (-12-) from the left shoulder (-14-) and the right shoulder (-19-)
Pelvis	Motion of the pelvis (-1-) in the forward-facing direction
	Sideways motion of the pelvis (-1-)
	Vertical motion of the pelvis (-1-)



PAIN LEVEL| Feature selection: Stretching & Flexion

Body Part	Kinematic Features
Pelvis	Vertical velocity of pelvis
Neck	Amount of neck displacement
Spine	Amount of trunk flexion before buttocks lift
	Amount of trunk flexion throughout movement
Hip	Hip and knee angles at buttocks lift
Time	Duration

PAIN LEVEL| Feature selection: Sit-to-Stand

Duration

Vertical velocity of pelvis

Amount of neck displacement

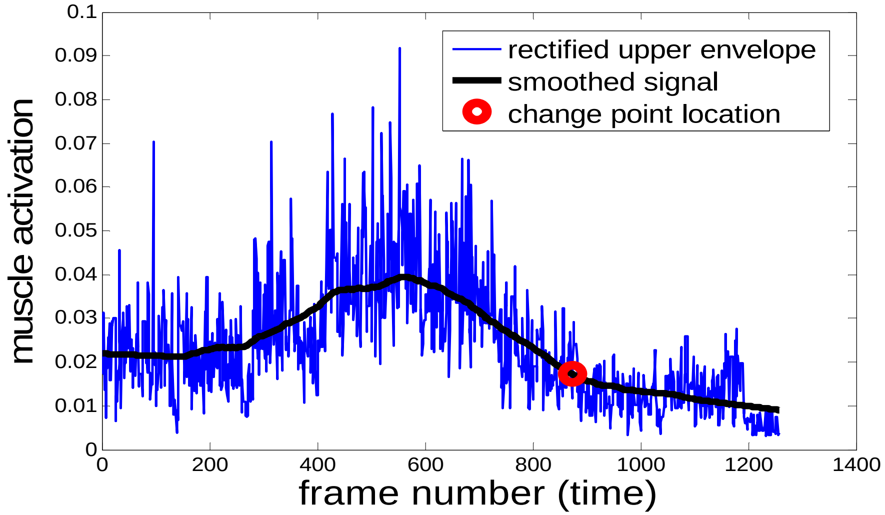
Amount of trunk flexion before buttocks lift

Amount of trunk flexion throughout movement

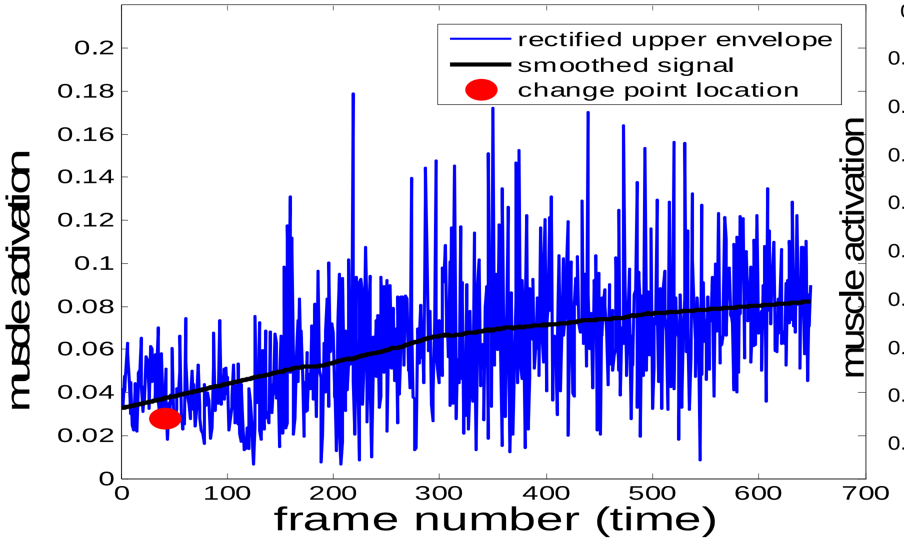
Hip and knee angles at buttocks lift

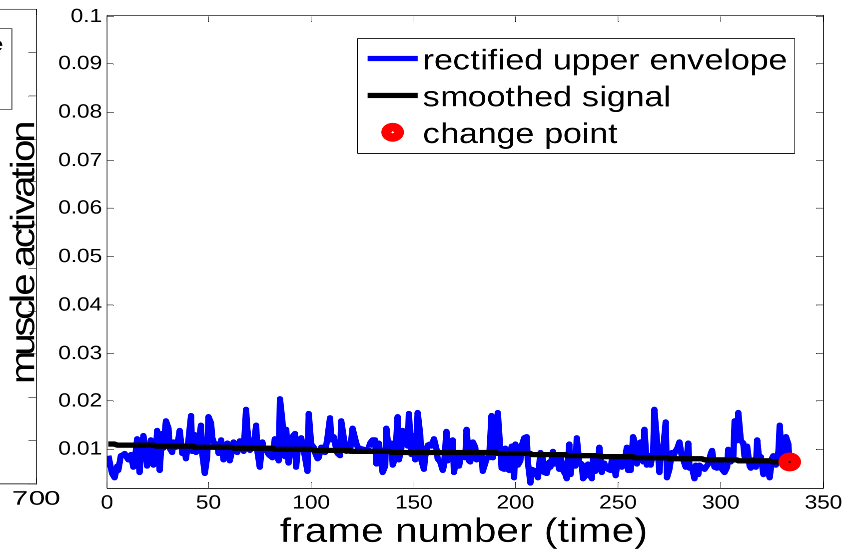
PAIN LEVEL| Feature selection: Muscle Activity

A typical muscle activation pattern in flexion



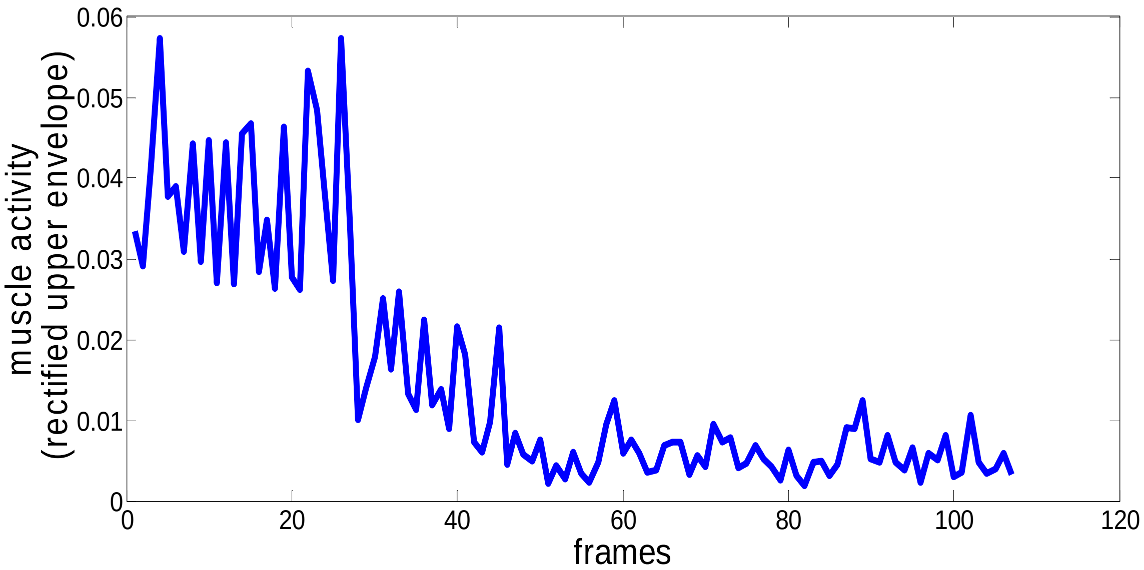
Patterns due to chronic pain: lacking deactivation (left) and lack of activation (right)

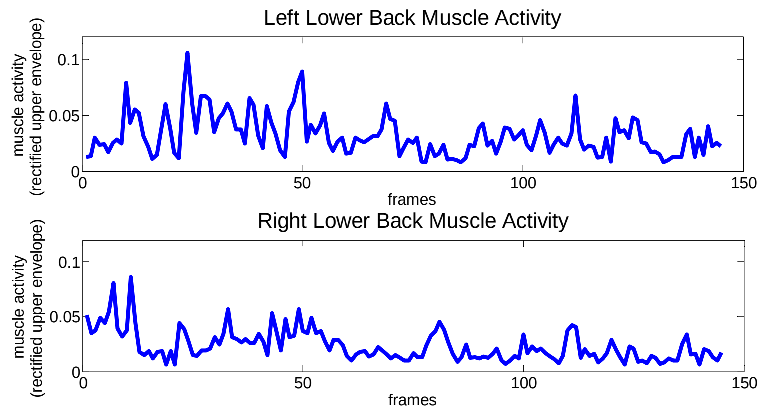


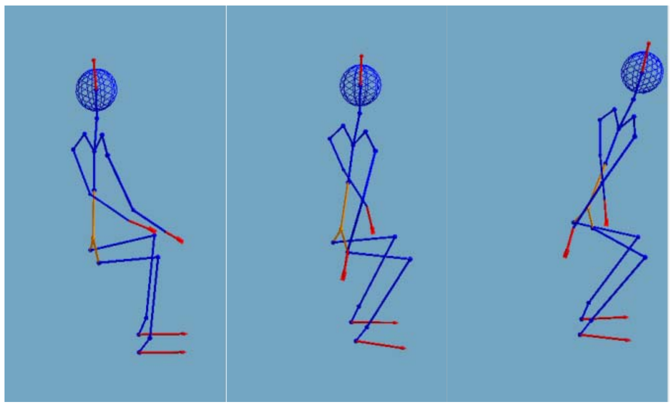


PAIN LEVEL| Feature selection: Muscle Activity

A typical muscle activation pattern in sit-to-stand







Automatic Pain Prediction - Results

		Prediction in Stretch Forward		
		Control	Low-Pain	High-Pain
Ground Truth	Control	17 (**89.4%**)	1 (5.3%)	1 (5.3%)
	Low-Pain	0 (0%)	13 (**86.7%**)	2 (13.3%)
	High-Pain	0 (0%)	3 (20%)	12 (**80%**)

		Prediction in Full Flexion		
		Control	Low-Pain	High-Pain
Ground Truth	Control	6 (**100%**)	0 (0%)	0 (0%)
	Low-Pain	0 (0%)	6 (**100%**)	0 (0%)
	High-Pain	0 (0%)	0 (0%)	6 (**100%**)

		Prediction in Sit-to-Stand		
		Control	Low-Pain	High-Pain
Ground Truth	Control	24 (**61.5%**)	4 (10.3%)	11 (28.2%)
	Low-Pain	6 (14.0%)	33 (**76.7%**)	4 (9.3%)
	High-Pain	11 (28.2%)	5 (12.8%)	23 (**59.0%**)

Olugbade, et al. (2014). Bi-Modal Detection of Painful Reaching for Chronic Pain Rehabilitation Systems. ICMI'14 . And follow-up in press at ACII'15

IMPROVING PERFORMANCES| Idiosyncrasy

Biases caused by idiosyncratic behaviours has significant effect on affect recognition performances

OrthoMTL	Transfer Learning

• Aim: Perform inference on new subjects when no information is provided
• Assumptions: the features which are influential for affective recognition
  • confound identity recognition
  • are orthogonal to the ones for identity
	• A few instances of the target subjects are available
	• Assumptions:
	  • commonalities exist within a group of subjects expressing the same emotion
	  • idiosyncrasies affect the instantiation of such communalities

Romera-Paredes, B., Min, H. A., Bianchi-Berthouze, N., Pontil, M. Multilinear Multitask learning. *ICML'13*

ILHAIRE: Laughter-aware conversational agents
(EU-FP7 2011-2014)

Detecting laughter types in body cues

http://www.ilhaire.eu/

LAUGHTER| Interacting with a laughter-capable avatar

LAUGHTER| Data collection

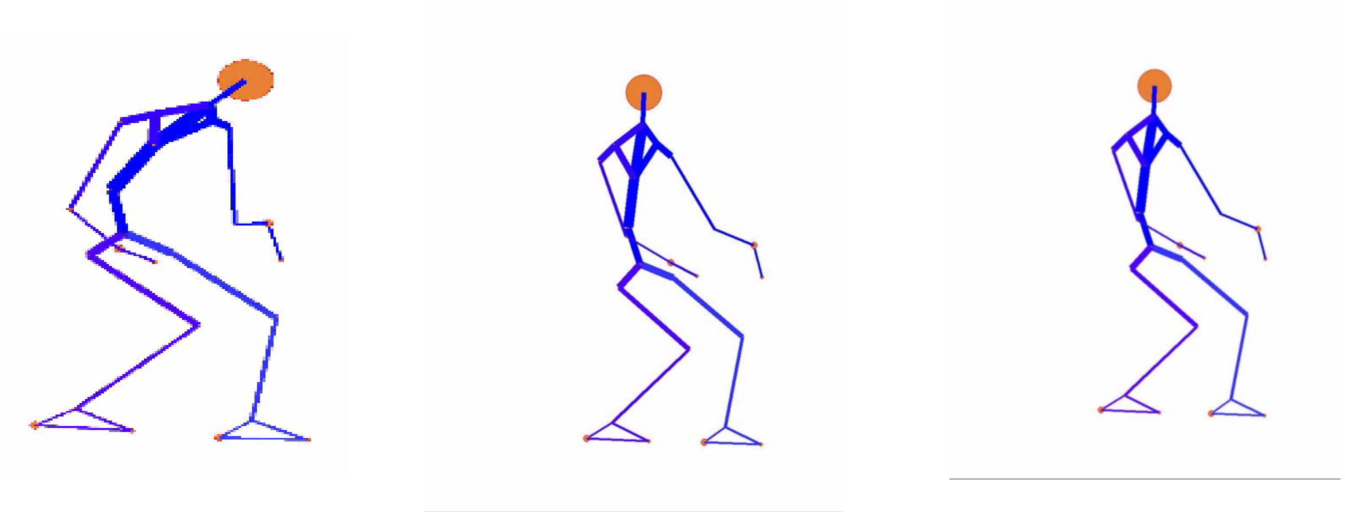
- Which body movements lead to the perception of different laughter types?

Laughter type	Data collection scenarios
Hilarious	Collaborative games e.g. Pictionary
	Rapid-fire tasks e.g., tongue twisters
Social	Conversation during "rest" periods
Awkward	YouTube videos
Fake	Explicit request to laugh

Griffin, H. J., et al. (2013). Laughter Type Recognition from Whole Body Motion. *IEEE ACII'13*

LAUGHTER | Data collection

Hilarious
Social
Awkward
Fake
No laughter



9 pairs of participants
126 clips selected

(UCL Dataset available at www.ilhaire.eu)

LAUGHTER | Perceptual Study

- 32 observers (17 male, 15 female, mean age 33.0)

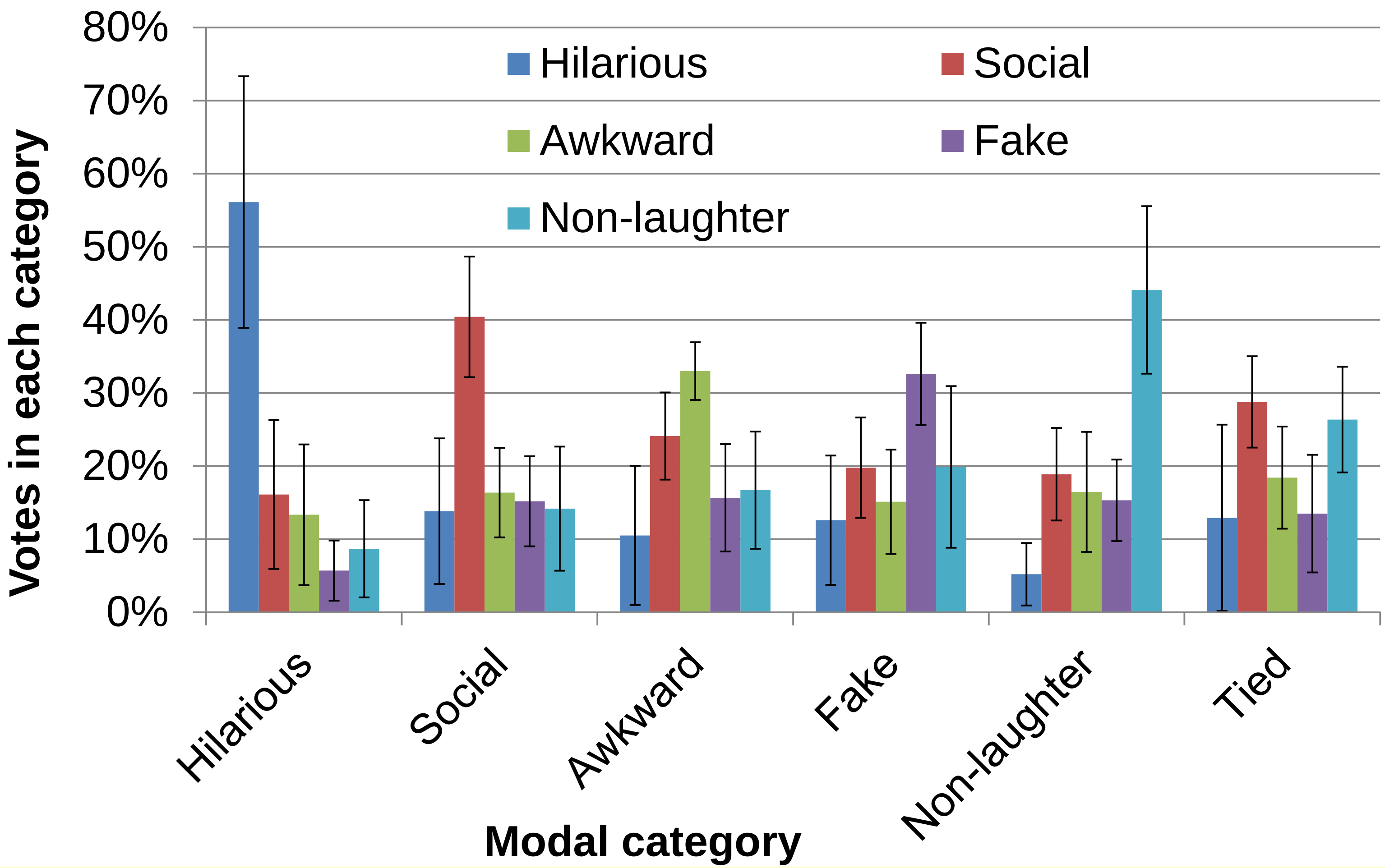
- Laughter categorisation:
  - Hilarious
  - Social
  - Awkward
  - Fake
  - Non-laughter

- Definitions and examples given

  "Social: This may be polite laughter as part of a conversation. It can show an acknowledgement of what another person has said is correct or show courtesy and good manners to the speaker.

  Example: Someone is having a conversation with a friend and is laughing as a way of acknowledging what their friend is saying and showing that they are enjoying their friend's story/anecdote."

LAUGHTER| Modal category and Label distribution



Griffin, H. J., et al. (2015). IEEE Trans. On Affective Computing

Griffin, H. J., et al. (2013). Laughter Type Recognition from Whole Body Motion. *IEEE ACII'13*

Body Part	Features returning max, min, range
Hands distances	Distance between hands
	Distance between hands and head
	Distance between hands and hip
Trunk bending	Angle at lower spine joint
	Angle at upper spine joint
	Angle at neck joint
	Sum of all spine angles
Trunk bending direction	Anterior-posterior component of lower spine→upper-spine segment direction
	Anterior-posterior component of upper-spine→neck segment direction
	Anterior-posterior component of neck→head segment direction
	Lateral component of lower spine→upper-spine segment direction
	Lateral component of upper-spine→neck segment direction
	Lateral component of neck→head segment direction
	Rotation of shoulders relative to hip line

Metrics	Features returning single value for each animation
Movement	Duration
Energy	Energy at elbow joint (max of left and right)
	Energy at shoulder joint (max of left and right)
	Energy at hip joint (max of left and right)
	Energy at knee joint (max of left and right)
	Energy at lower spine joint
	Energy at upper spine joint
	Energy at neck joint
Shoulder rotation	Azimuthal rotation of shoulders in global space
Lower body distances	Ankle trajectory distance (max of left and right)
	Knee trajectory distance (max of left and right)
Smoothness	Smoothness of shoulder trajectory relative to upper spine (mean of left and right)
Displacement	Range of superior-inferior shoulder displacement (mean of left and right)
	Correlation of left and right shoulder superior-inferior displacement
	Power in 4-6Hz band of superior-inferior shoulder displacement (mean of left and right)

SITTING POSTURES	MIN	MAX	Range
Distance between hands			a,B
Distance between hands and head			A,B
Distance between hands and hip			A,b
Angle at lower spine joint			A,B,c
Angle at upper spine joint		a,b	A,B,c
Angle at neck joint		a,b	A,B
Sum of all spine angles			A,B,c
Anterior-posterior component of lower spine→upper-spine segment direction			A,B
Anterior-posterior component of upper-spine→neck segment direction			A,B
Anterior-posterior component of neck→head segment direction		a,b	A ,B,c
Lateral component of lower spine→upper-spine segment direction		a,b	A,B
Lateral component of upper-spine→neck segment direction			A,B,c
Lateral component of neck→head segment direction		a,b	A ,B,c
Rotation of shoulders relative to hip line		a,b	A,B,c

STANDING POSTURES	MIN	MAX	Range
Distance between hands			x,y
Distance between hands and head	x,y		x,y
Distance between hands and hip		x,Y	x,y
Angle at lower spine joint	x,y		X,Y
Angle at upper spine joint	x,y		X,Y,z
Angle at neck joint	y		x,y
Sum of all spine angles	x,y		X,Y
Anterior-posterior component of lower spine→upper-spine segment direction		x,y	X,Y
Anterior-posterior component of upper-spine→neck segment direction		x,y,z	X,Y,z
Anterior-posterior component of neck→head segment direction		x,y	X,Y
Lateral component of lower spine→upper-spine segment direction		x,Y	
Lateral component of upper-spine→neck segment direction		x,y	x,y
Lateral component of neck→head segment direction		x,y	x,y
Rotation of shoulders relative to hip line	X,y,z		

Features returning single value for each animation	Sitting	Standing
Duration	A,B	y
Energy at elbow joint (max of left and right)		
Energy at shoulder joint (max of left and right)	A,B,c	X,y,Z
Energy at hip joint (max of left and right)	a,b,c	
Energy at knee joint (max of left and right)	b,c	
Energy at lower spine joint	a,b,c	x
Energy at upper spine joint	a,b	x,y
Energy at neck joint	A,B,c,x,y	
Azimuthal rotation of shoulders in global space	A,B	
Ankle trajectory distance (max of left and right)	a,B,c	
Knee trajectory distance (max of left and right)	A,B,C	x,y,z
Smoothness of shoulder trajectory relative to upper spine (mean of left and right)	a	
Range of superior-inferior shoulder displacement (mean of left and right)	A,B	
Correlation of left and right shoulder superior-inferior displacement		
Power in 4-6Hz band of superior-inferior shoulder displacment (mean of left and right)		

LAUGHTER TYPES| Modeling and evaluation

Short name	**ML Algorithms**
(K)SVR	Linear and Kernel Support Vector Regression
k-NN	*k*-Nearest Neighbour
MLP	Multi Layer Perceptron with Softmax
RF	Random Forest
LASSO	Least Absolute Shrinkage and Selection Operator

Short name	**Error metrics**
MSV	Mean Square Error
CS	Cosine Similarity
TMR	Top Match Rate
RL	Ranking Loss: this metric calculates the average fraction of label pairs that are reversely ordered for an instance.

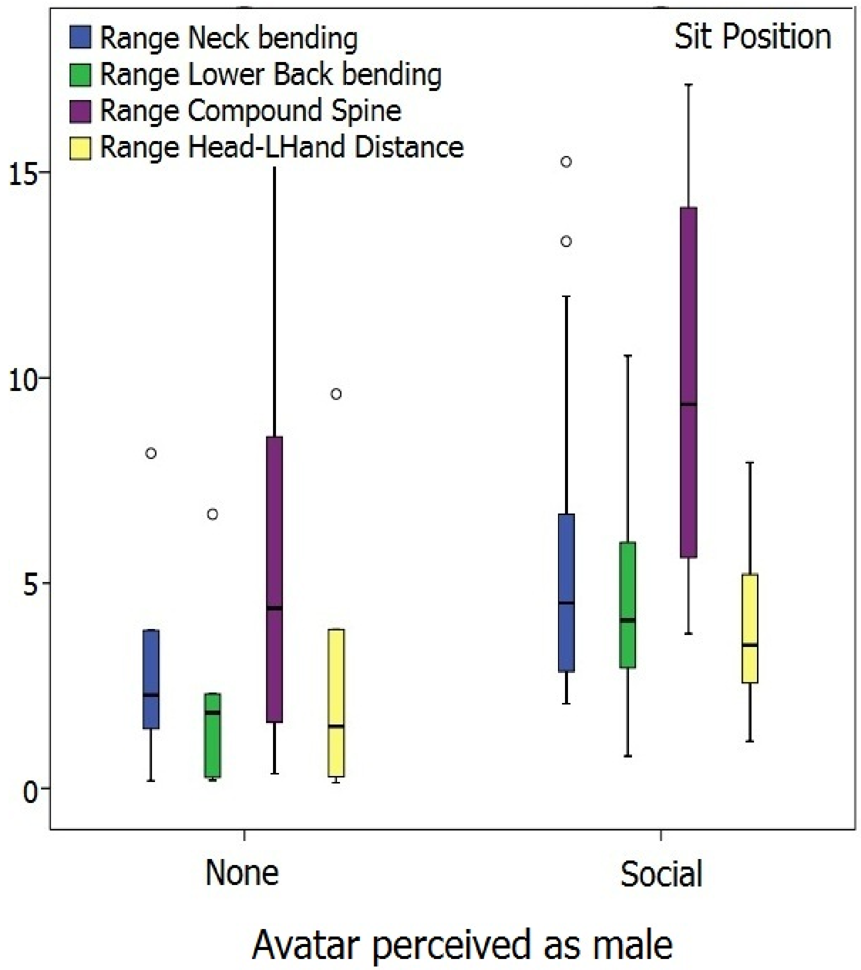
LAUGHTER TYPES| Automatic recognition

	MSE ↓	*CS* ↑	*TMR* ↑	*RL*↓
k-NN	0.015 (0.005)	0.89 (0.04)	0.52 (0.21)	0.30 (0.05)
SVR	0.014 (0.005)	0.89 (0.03)	0.50 (0.18)	0.29 (0.08)
LASS0	0.015 (0.005)	0.89 (0.03)	0.43 (0.22)	0.30 (0.08)
MLP	0.017 (0.007)	0.87 (0.05)	0.50 (0.18)	0.32 (0.05)
RF	**0.010 (0.003)**	**0.92 (0.03)**	**0.59 (0.18)**	**0.26 (0.06)**
Observers	0.02 (0.003)	0.95 (0.01)	0.85 (0.03)	0.10 (0.01)

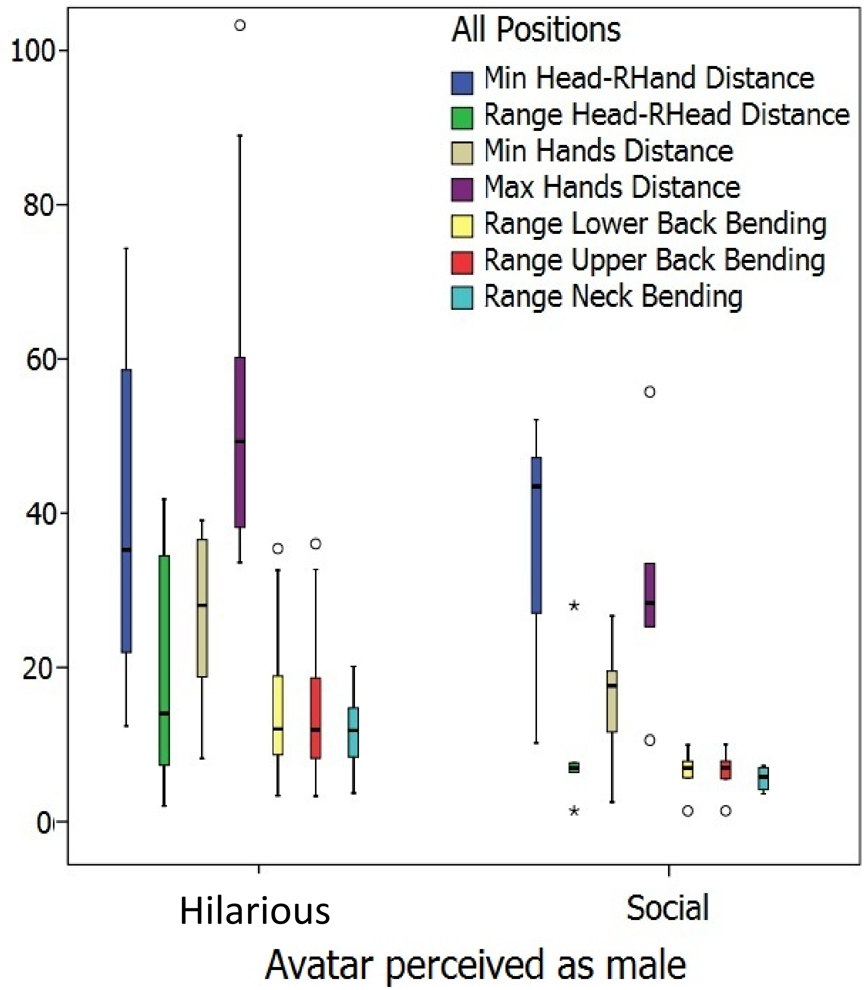
Griffin, H. J., et al. (2013). Laughter Type Recognition from Whole Body Motion. *IEEE ACII'13*

LAUGHTER| Gender effect

Avatar perceived as female:
Social



Avatar perceived as female:
Hilarious



CONCLUSIONS

- Interesting opportunity in physical rehabilitation
  - It's not enough to measure physical progress … psychological progress is even more important
- Important modality for affect recognition
  - The face doesn't say everything ---
  - Good recognition performance on naturalistic body expressions
- Means for experience
  - Gender bias in interpreting laughter …. And surely for pain

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EMO & PAIN REHABILITATION

UCL EPSRC NHNN SEVENTH FRAMEWORK PROGRAMME