Encouraging physical activity of diabetes patients

Elad Yom-Tov
Microsoft Research Israel & Technion, Israel Institute of Technology

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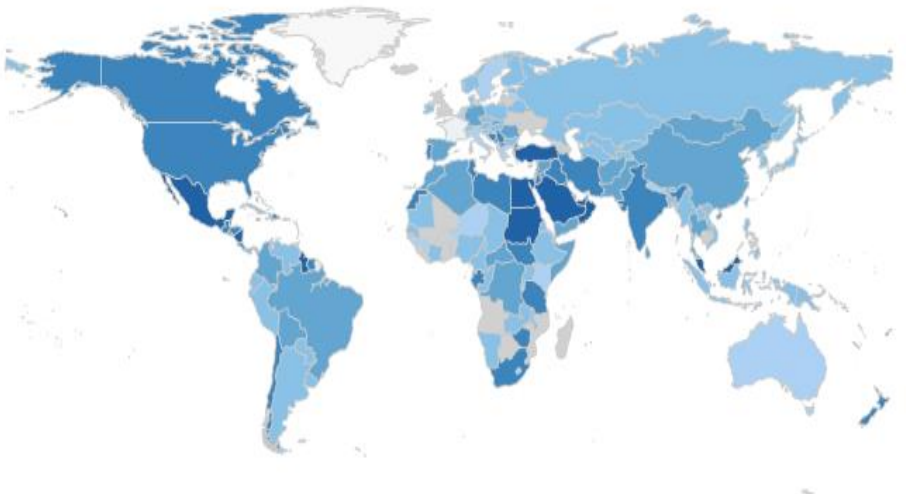
Type 2 diabetes

- Type 2 diabetes (T2DM) affects around 6% of the world's population (285 million people).
- T2DM is strongly associated with obesity and limited physical activity
  - Cochrane Review: "Interventions aimed at increasing exercise combined with diet are able to decrease the incidence of type 2 diabetes mellitus in high risk groups" (Exercise or exercise and diet for preventing type 2 diabetes mellitus, 2008)
- Doctors recommend physical activity to patients, stressing both the benefits of activity and the harm from not performing activity,
  - but patients rarely reach recommended weekly exercise goals (usually 2-3 hours of walking).

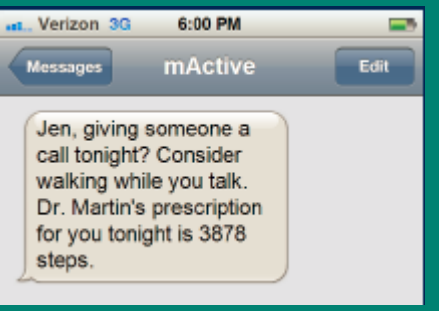


Past work: Encouraging activity

- The most useful strategies to encourage physical activity include:
  - Physical activity profiles
  - Goal setting
  - Real-time feedback
  - Social support networking
  - Online expert consultation

- Intervention effects reported in the literature a
  - As are sample sizes…

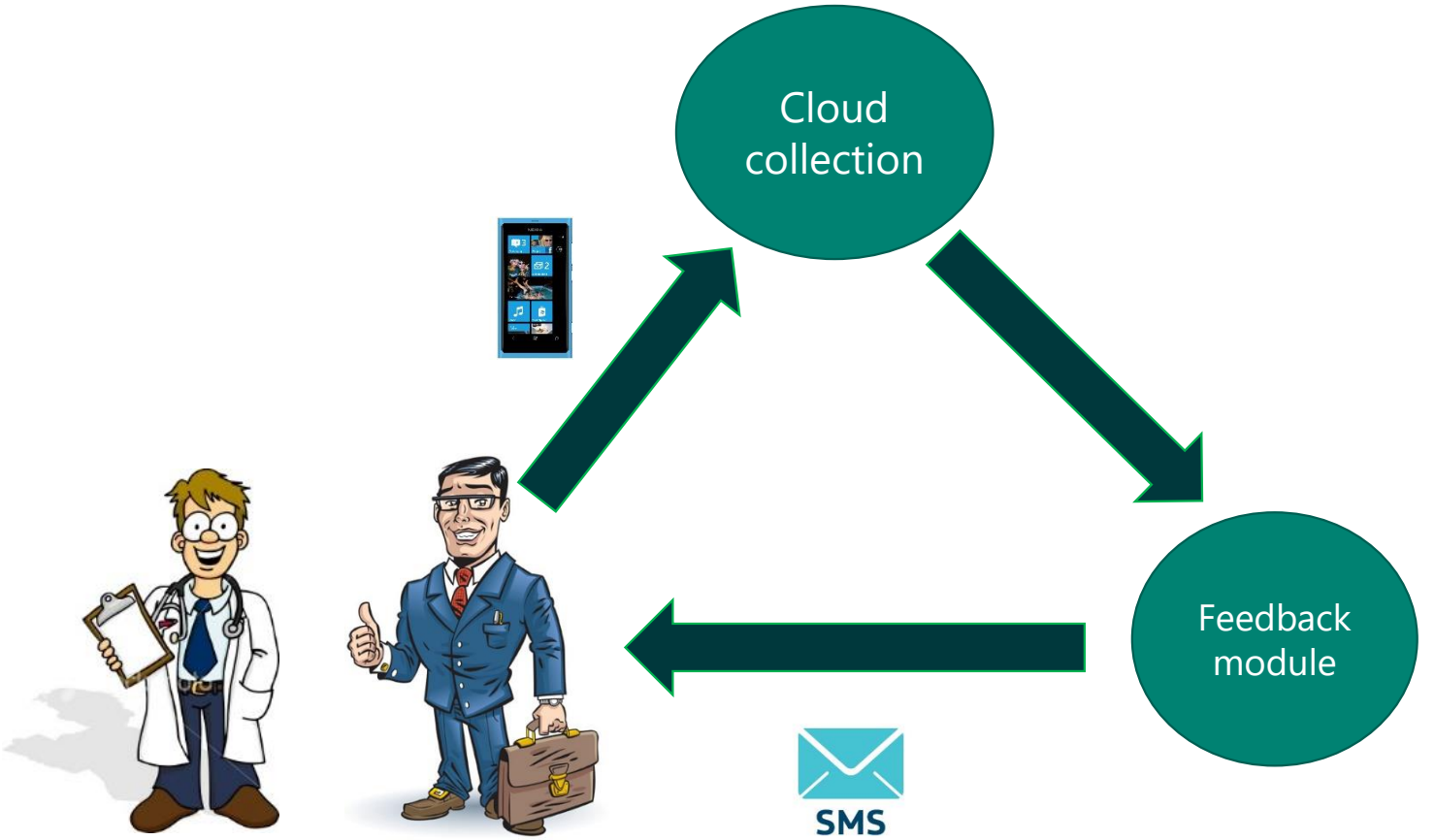
- "Smartphone strategies to influence physical ac
  rather than theory-based approaches"



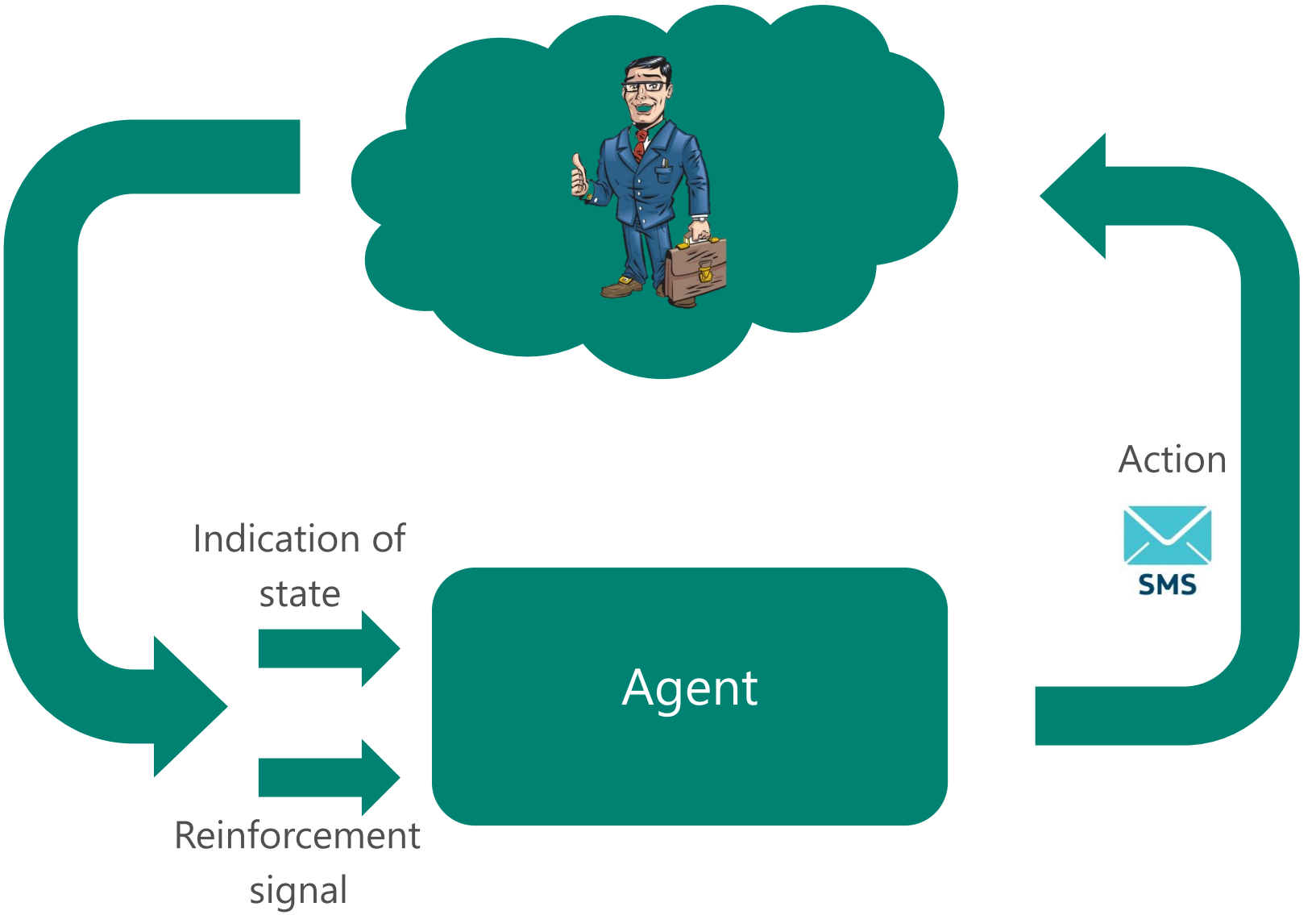
Martin, Seth S., et al. "mActive: A Blinded, Randomized mHealth Trial Supporting Digital Tracking and Smart Texting for Promotion of Physical Activity." *Circulation* 131.Suppl 1 (2015): A11-A11.

- Bort-Roig, J., Gilson, N. D., Puig-Ribera, A., Contreras, R. S., & Trost, S. G. (2014). Measuring and influencing physical activity with smartphone technology: A systematic review. *Sports Medicine, 44*(5), 671-86.
- Fanning, J., Mullen, S.P., McAuley E. (2012) Increasing Physical Activity With Mobile Devices: A Meta-Analysis. JMIR, 14(6), e161

Our solution: Encourage physical activity through personalized messages



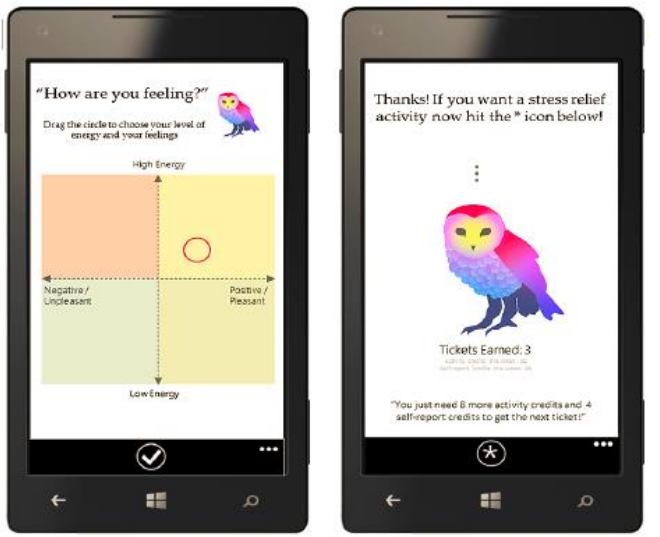
Mapping our problem to RL



Past work: Reinforcement Learning

- Micro-Randomized Trials in mHealth

- PopTherapy: Coping with stress through pop-culture
  - **Mary Czerwinski**



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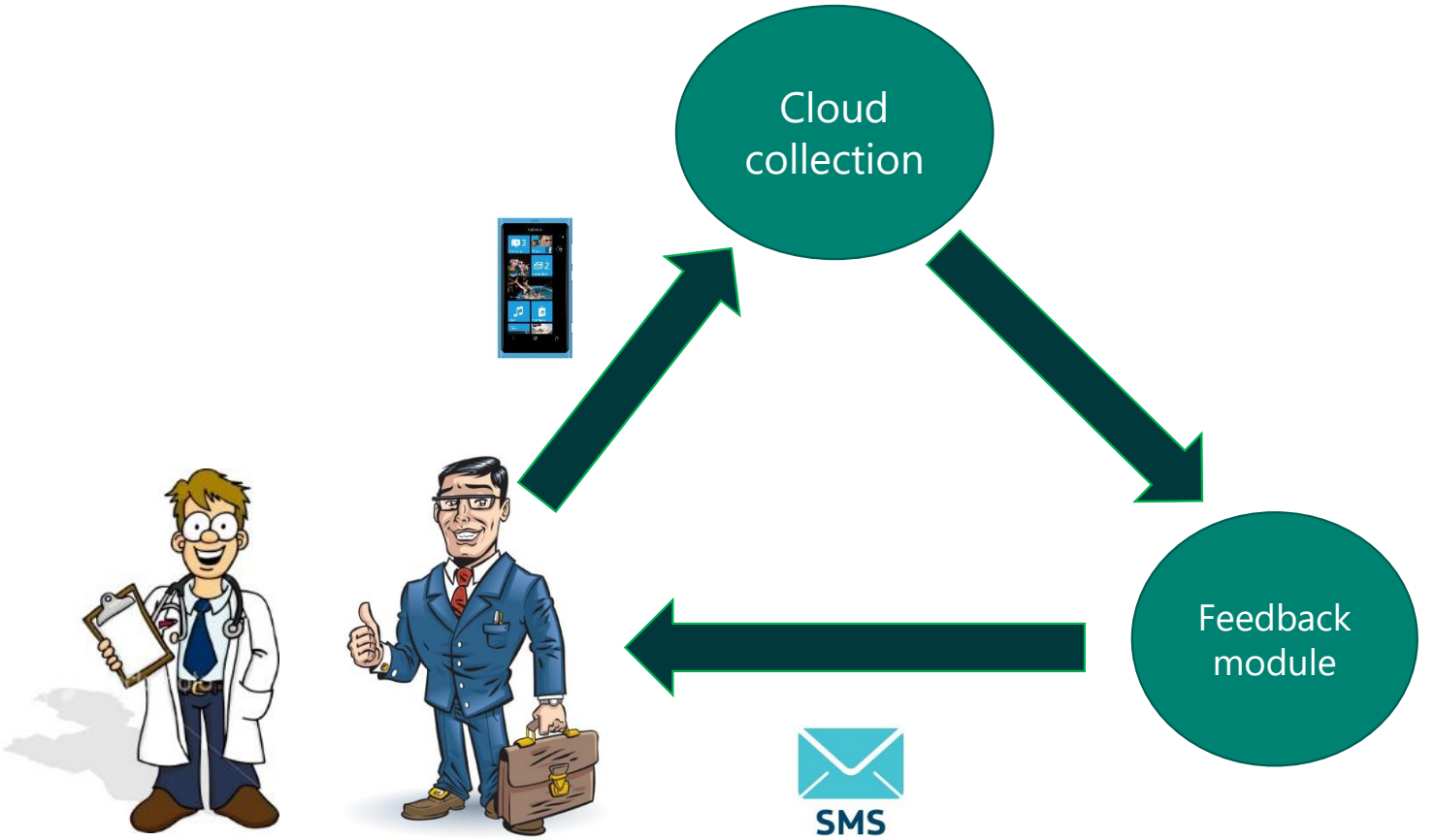


Design choices

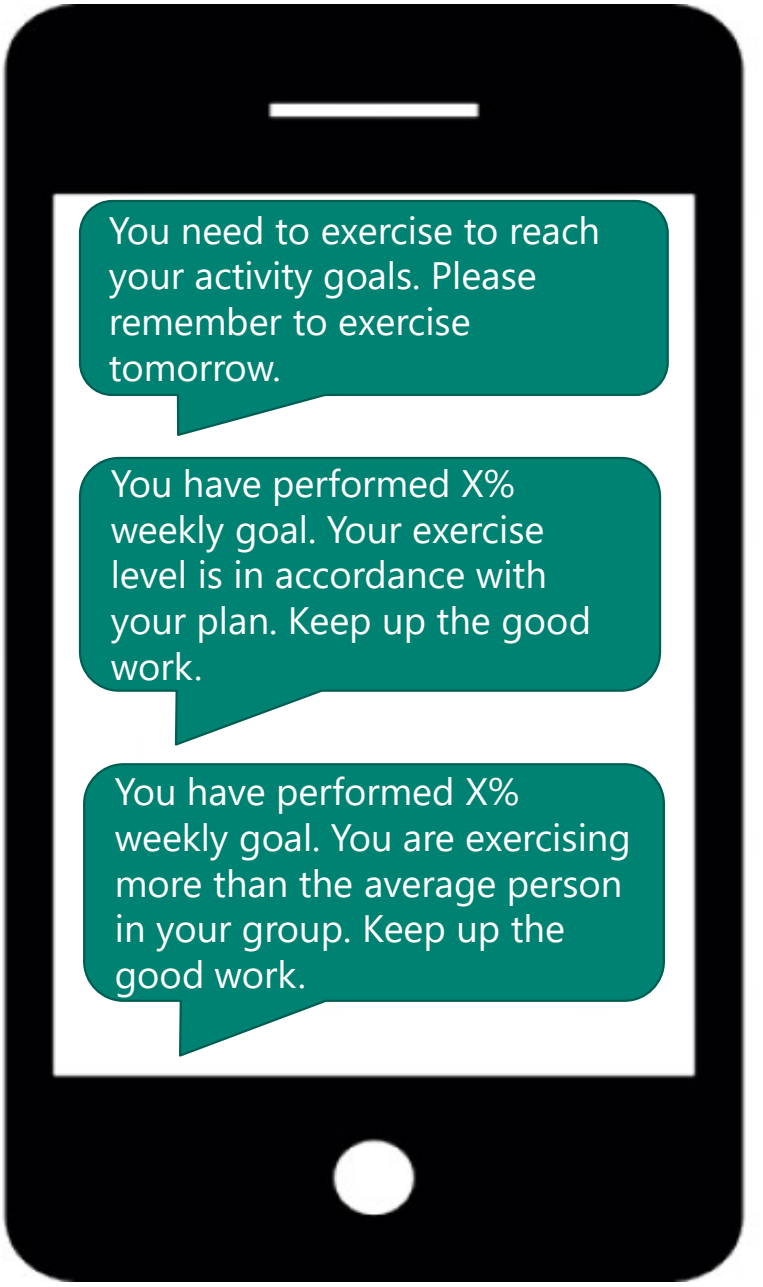
- Why cellphones?
  - “91% of people keep their phone within 3 feet, 24 hours a day” (Morgan Stanley Technology & Internet Trends)
  - “More than 70% of Fitbit purchasers from the first three quarters of 2014 churned before the end of the year.” (RockHealth)
- Why SMS?
  - Popular communication channel
  - Doesn't require users to open a dedicated app
- Why long walks?
  - Clinical significance
  - Battery life

Messages

Negative feedback:

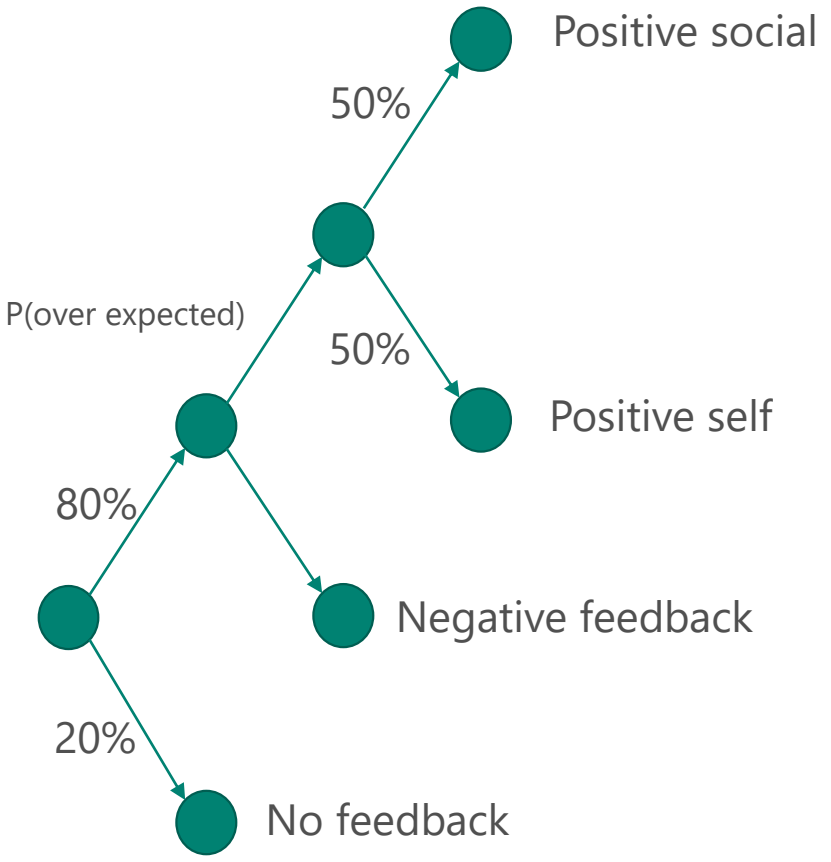
Positive feedback relative to self:

Positive feedback relative to others:



Control policies

- **Control policy**: Weekly reminders
- **Initial policy**: Based on insights from psychology
- **Learned policy**: Linear with interactions



Learned policy

- Activity attributes:
  - Number of minutes of activity in the last day
  - Cumulative number of minutes of activity this week
  - Fraction of activity goal
  - Fraction versus expected at this point in the week
- Demographics:
  - Age
  - Gender
- Feedback attributes:
  - Number of days since each feedback message was sent.

Learned policy classifier

- Let **X** be a vector of attributes and **y** the improvement in activity
- Similar to the **Kesler construction**, augment **X** with an action vector, **A** (Nx1), such that $\mathbf{A}_i$=1 iff action *i* was taken.
- When predicting, try all combinations of *i* and choose the one which provides the largest predicted improvement
- Apply Boltzmann sampling to perform exploration.

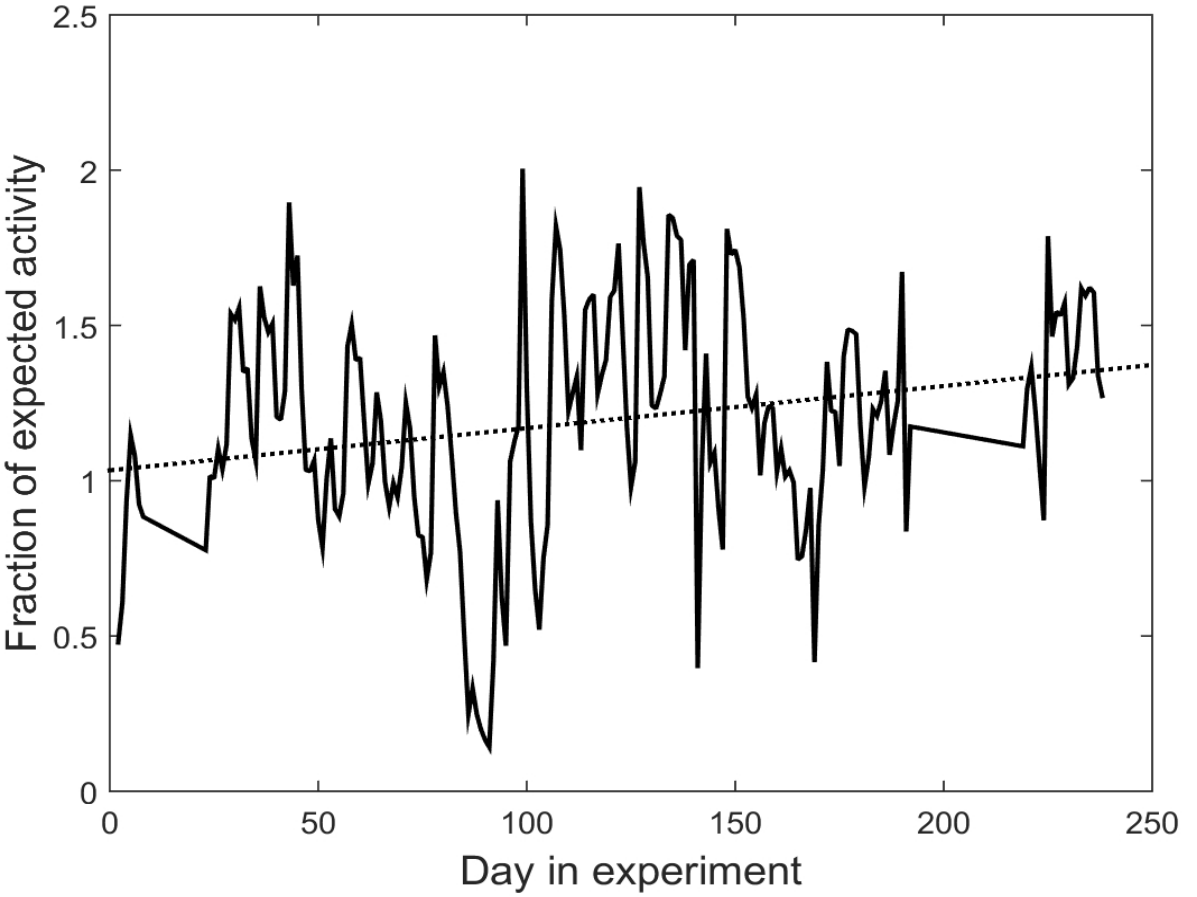
Clinical trial

- Clinical trial ran since August 2014.
- In total, 27 patients were recruited for a period of 6 months each, 1/3 served as controls.
- Recruitment criteria:
  - Adults with type 2 diabetes
  - Non-optimal glycemic control (HbA1c over 6.5%)
  - Sedentary lifestyle with no dedicated physical activity
  - Android-based smartphone with nightly WiFi access or data plan
  - Recruited at a tertiary hospital
- At recruitment, patients agreed to a workout plan
  - Number of sessions
  - Total duration
  - Schedule

Patient characteristics

	Personalized (n=20)	Control (n=7)
Age	58.7 (2.1)	55.1 (3.6)
Gender	8 female, 12 male	1 female, 6 male
Height	164.8 (4.1)	166.0 (9.7)
Weight	97.0 (5.0)	111.5 (12.9)
Initial HbA1c	7.73 (0.19)	8.12 (0.46)

Walking improvement

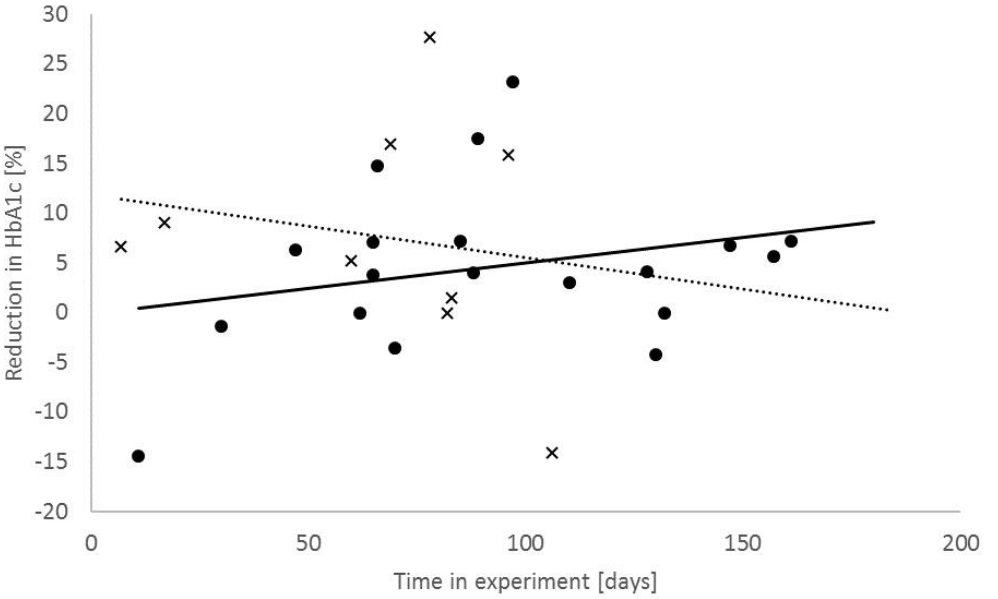


Walking and walking rate

	Slope of expected activity	Slope of the rate of walking
Control	-0.004 (0.002)	-0.010 (0.007)
Initial policy	-0.001 (0.008)	-0.009 (0.005)
Personalized	+0.012 (0.002)	+0.002 (0.005)

Glycated hemoglobin (HbA1c) levels

Allocation to the personalized policy, higher initial HbA1c, and lower activity targets led to a superior reduction in HbA1c (R^2=0.405, $P<10^{-4}$).



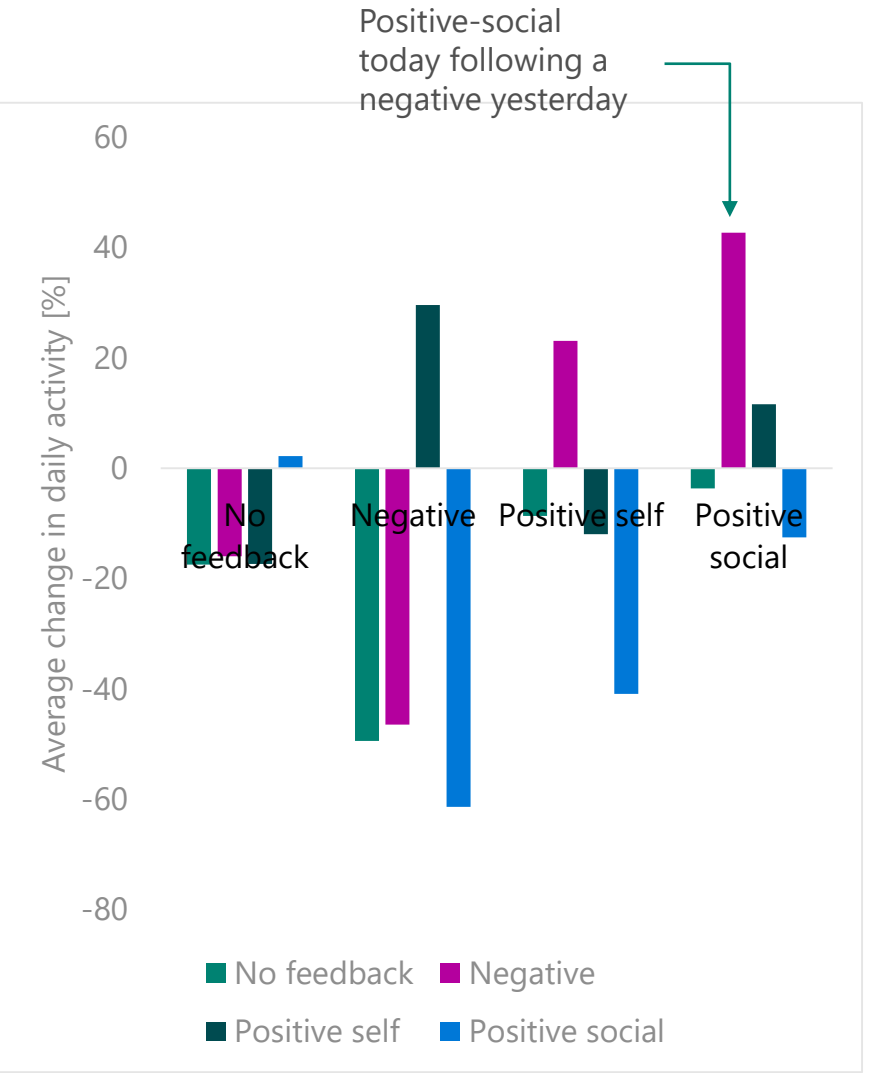
Patient satisfaction

Question	Percent answering "yes"		P-value
	Personalized	Control	
Did you increase your level of physical activity since joining the experiment?	0.556	0.667	0.73
Did the SMS messages help you increase the frequency of physical activity?	0.800	0.000	0.01
Did the SMS messages help you maintain your physical activity?	0.875	0.333	0.07
Do you think you received enough messages to improve your activity?	0.778	1.000	0.46

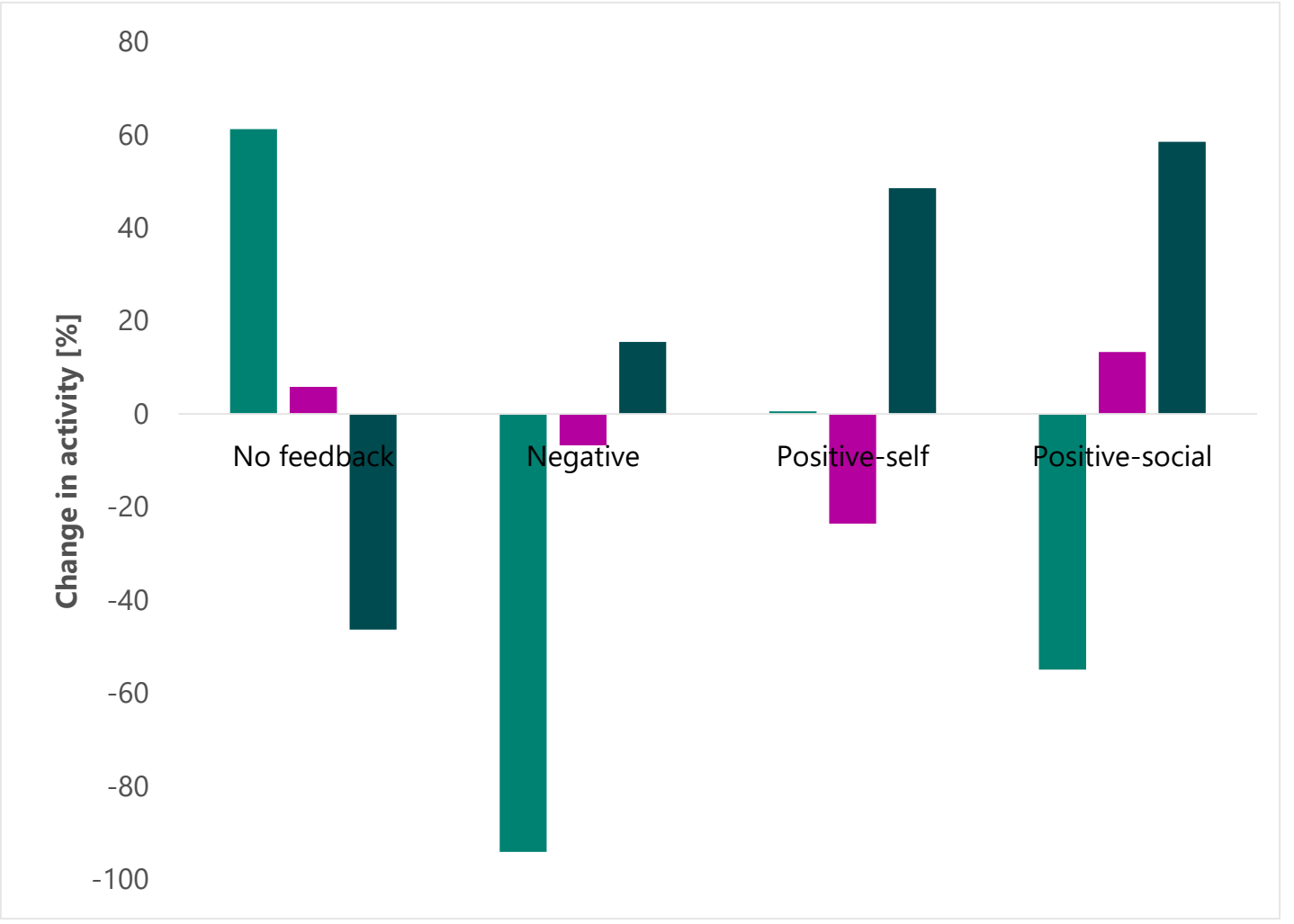
Daily feedback effectiveness

Pairs of days

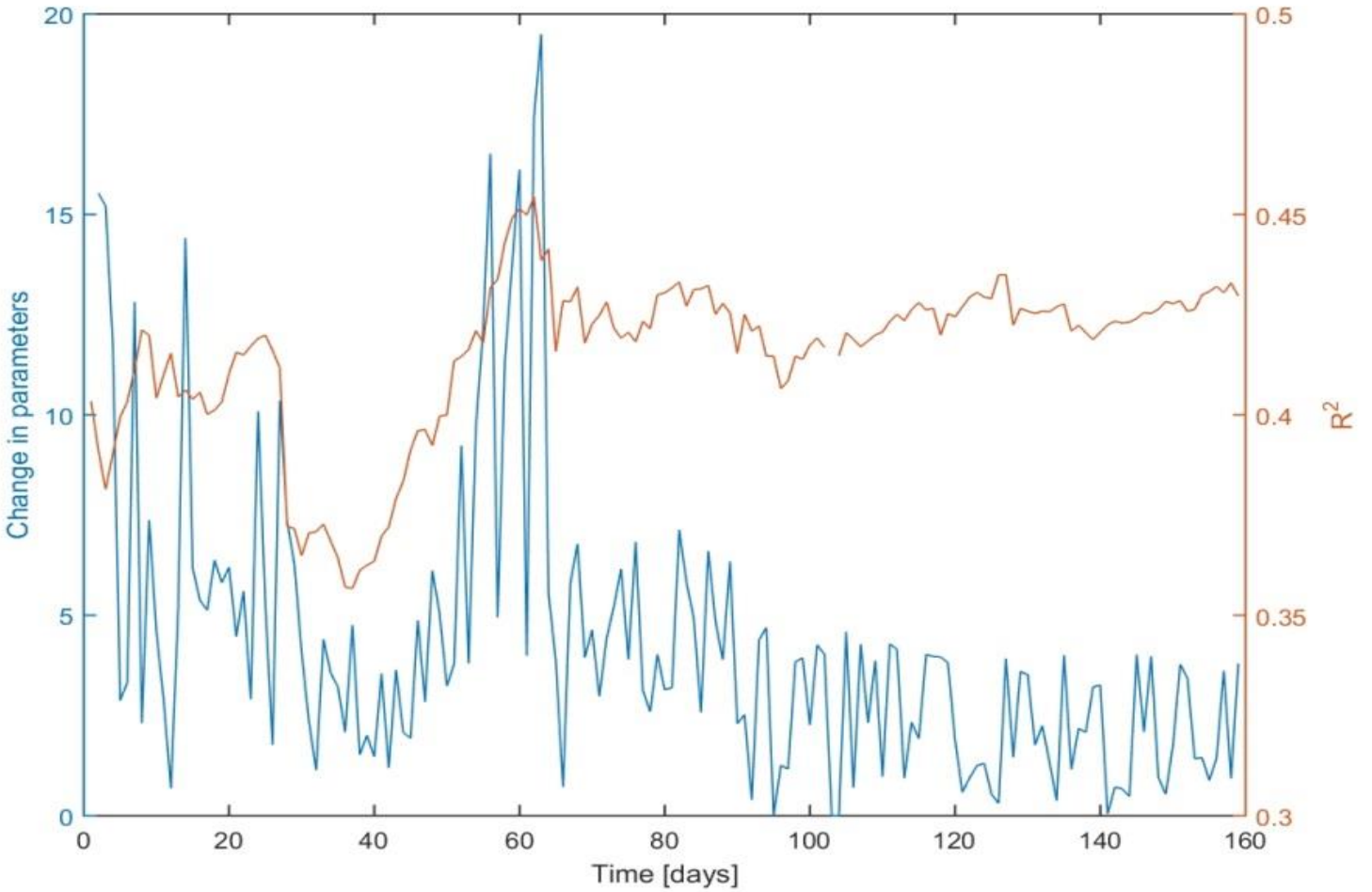
- Sending the same message every day doesn't work, even if that message is, on average, very effective.
- The classifier learns to effectively use sequences of actions.



Clustering


80
60
40
20
0
-20
-40
-60
-80
-100
Change in activity [%]
No feedback
Negative
Positive-self
Positive-social

Learned policy over time



A few more insights

- Things that didn't work:
  - Sending the same information to spouses
  - Badges
  - No restrictions on the policies
- Some things we thought were easy, but were not:
  - Comparing the impact of different policies
  - Tracking users across cellphones

Encouraging activity of healthy people

- Recruited 140 healthy individuals.
- Two part message:
  - Informational (10 possible messages)
  - Task-oriented (29 possible messages)
- Example:

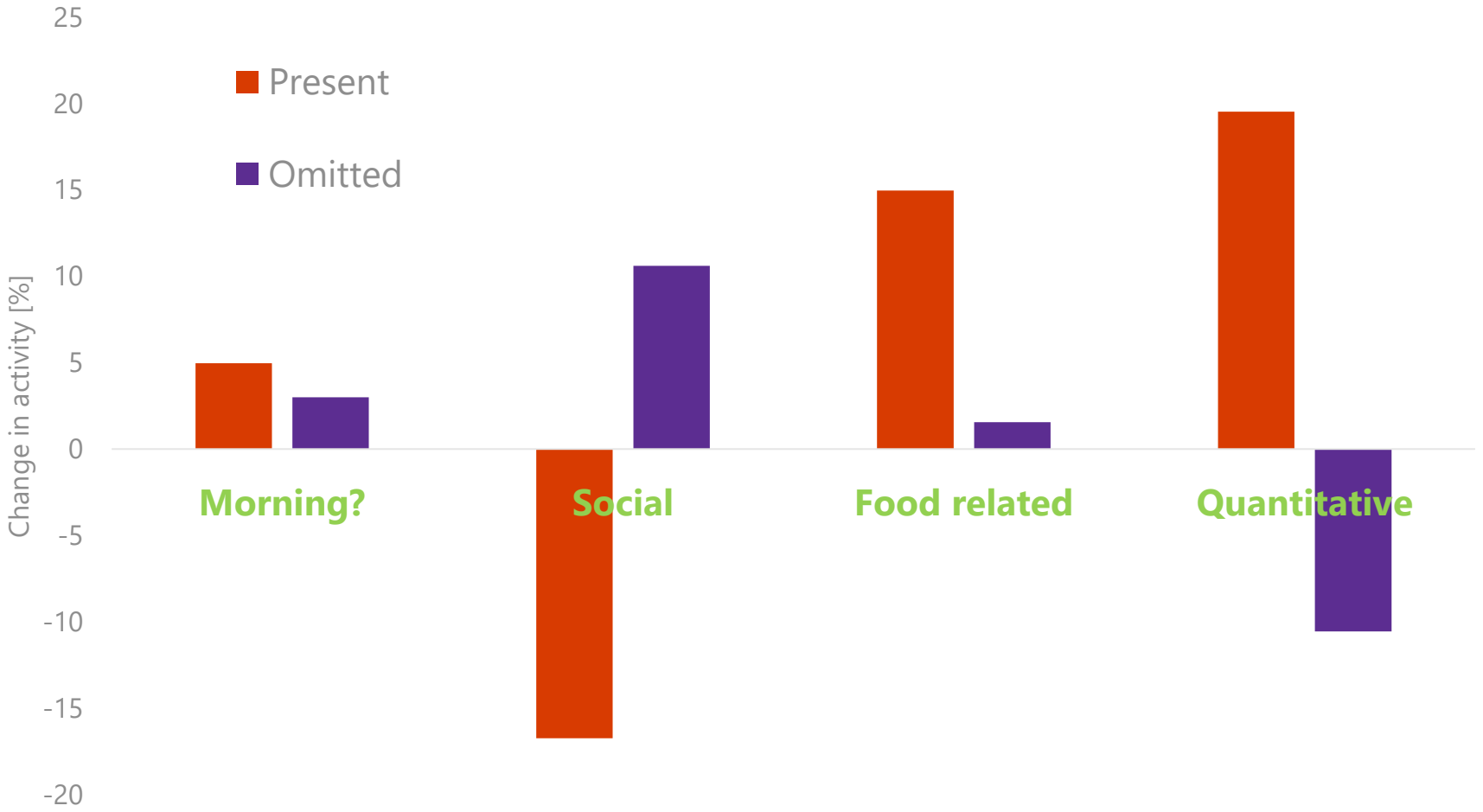
> Today you walked 3066 steps. This is more than most similar people. Keep up the good work!
> Challenge: Try taking 10 minutes to walk tomorrow morning.

Attribute	Value
Age	39.8 ± 9.0
Gender	22 Female, 120 male
Average step goal	7919 ± 2442

Base message effectiveness

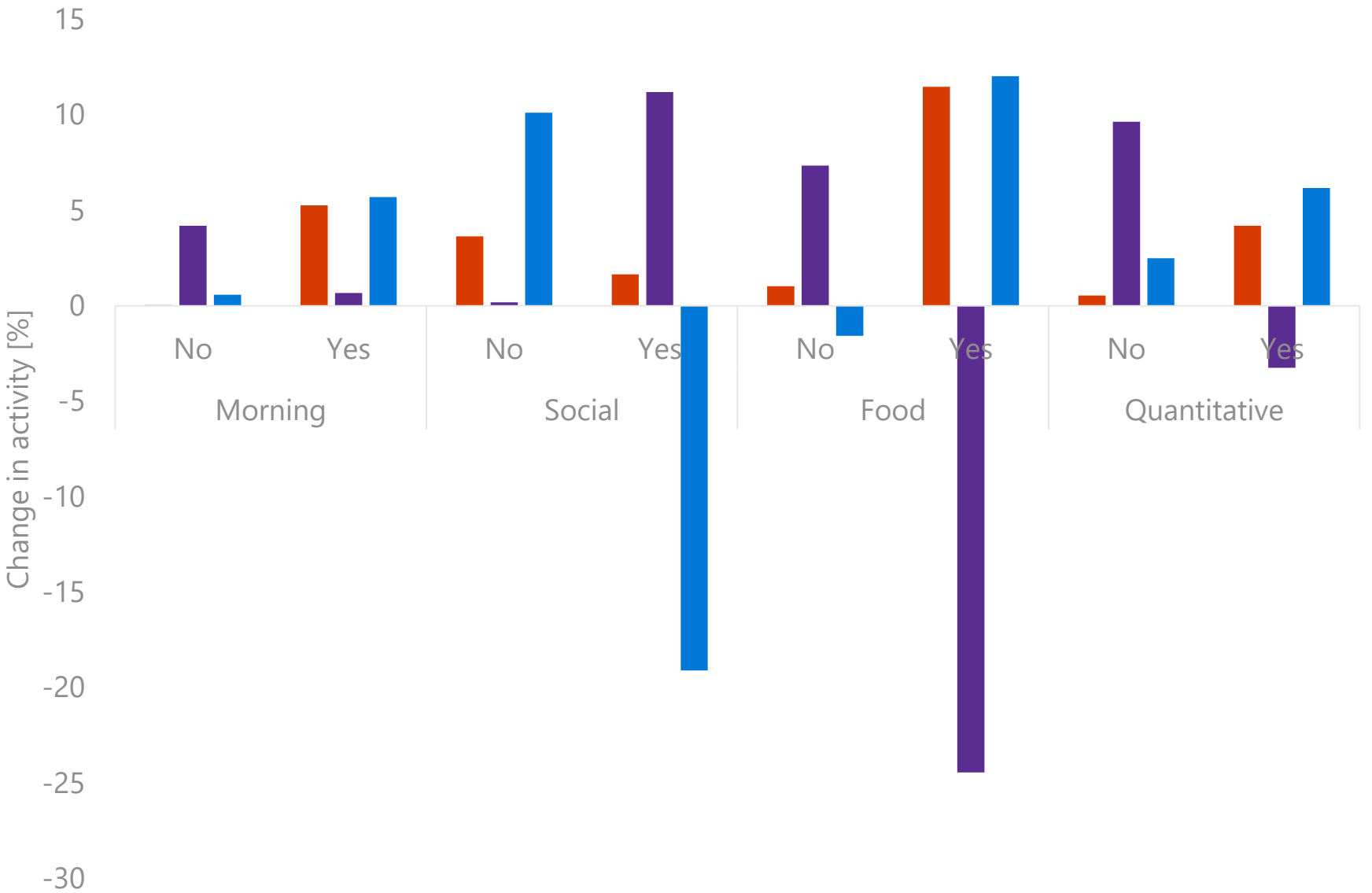
- Actions with at least 100 instances.
- Median changes shown.
- Statistically significant differences (ANOVA, $p<10^{-10}$).

Task message effectiveness



Social and quantitative are statistically significant (ANOVA, $P<0.05$).

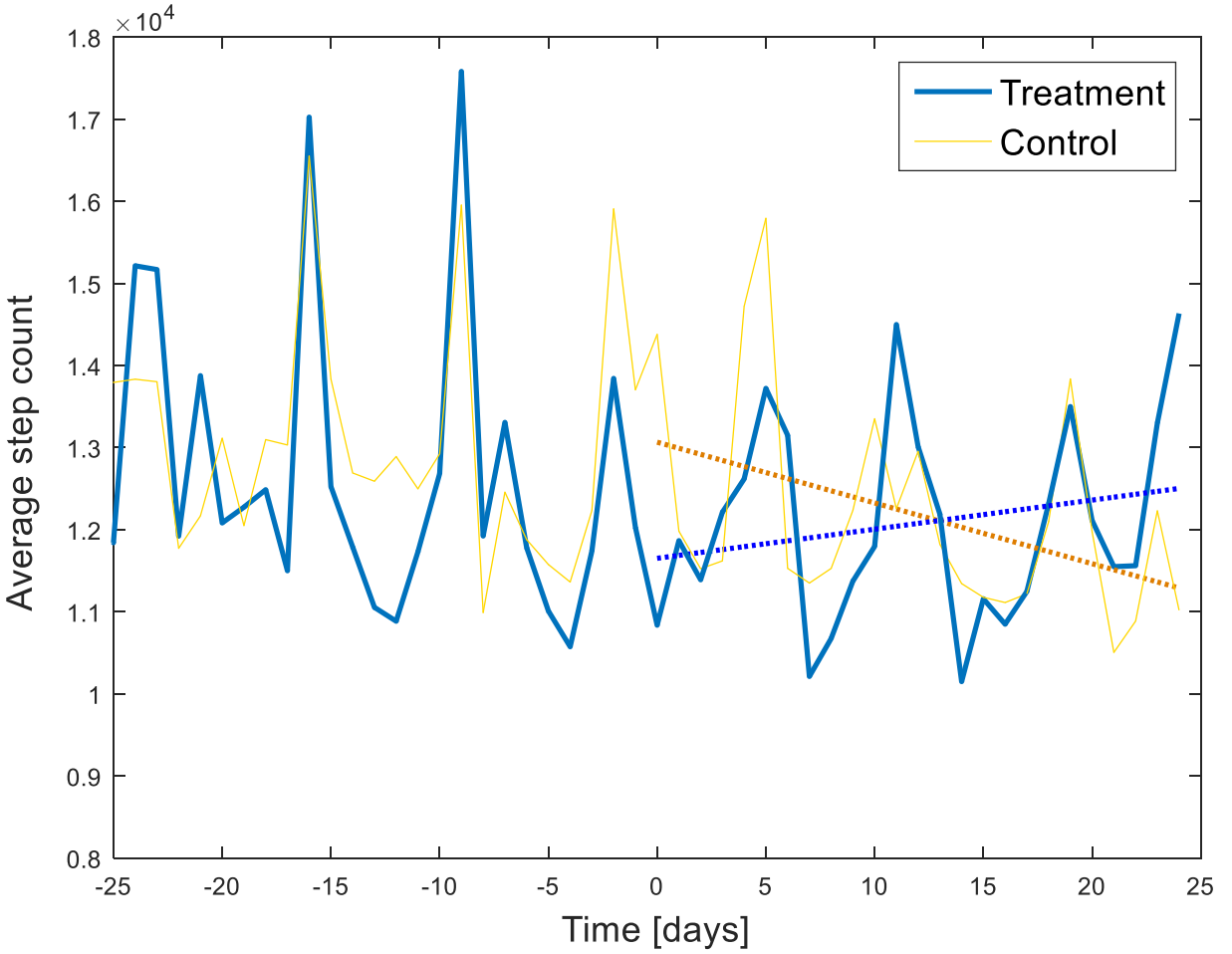
User clustering



Cluster demographics

	Cluster 1	Cluster 2	Cluster 3	Others
Male/Female [%]	91/9	82/18	71/29	82/18
Average age	40	39	38	40
Average step goal	7934	7773	8314	7974
Average actual to goal	66%	65%	67%	60%
Number	**53**	**33**	**14**	**39**

Total step count



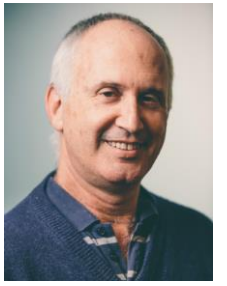
N=39, correlation>0.7, match by age, gender, step goal, and country

Summary

- People rarely maintain the recommended physical exercise regimen, even when clinically important
- In our clinical trial we have demonstrated the ability to maintain physical activity through tailored messages.
  - Learned policies are more effective than ones based on “best practices”.
- These results are applicable to other patient groups (obese, oncological), and probably to healthy populations too.
- There are interesting theoretical questions:
  - Evaluating new policies offline
  - Reconstructing the state space

Joint work with:

- Irit Hochberg (Rambam Hospital)
- Guy Feraru (Rambam Hospital)
- Mark Kozdoba (Technion)
- Shie Mannor (Technion)
- Moshe Tennenholtz (Technion)



CROWDSOURCED HEALTH

HOW WHAT YOU DO ON THE INTERNET WILL IMPROVE MEDICINE

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