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# Factors Influencing Quality of Experience of Commonly-Used Mobile Applications

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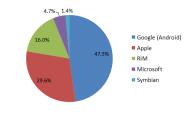


#### Mobile Phone Factor



#### Statistics

- US
  - 2010 31% of mobile phone users had smartphones [Kellogg, 2011]
  - 2012 50 % [Entner, 2010; Nielsen Stats 2012]
- EU5 (FR, ES, DE, IT, UK)
  - 50% [comScore MobiLens 2012]
- Worldwide
  - 2010 300 million sold [Cozza, 2011a]
  - 2012 500 million [Cozza, 2011b]

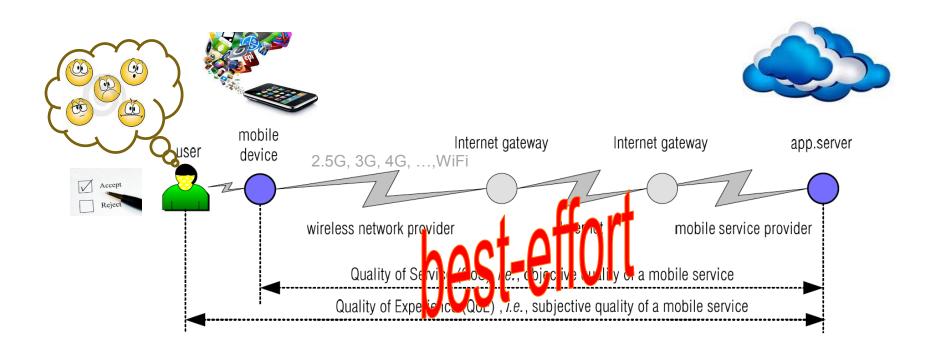


[comScore, Feb 2012]

- Smartphone getting closer [Dey, Wac et al., Ubicomp 2011]
  - Arm reach 53%
  - Arm + room reach 88%
- Mobile apps
  - For everything...



### (Interactive) Mobile Applications



#### QoE & QoS

- Quality of Experience (QoE)
  - "the overall acceptability of service, as perceived subjectively (i.e., qualitatively)
     by the user" [ITU-T, 2007]
- Quality of Service (QoS)
  - "a collective effect of service performances which determine the (objective)
     degree of satisfaction of a user" [ITU-T, 1993]
  - QoS requirements expressed quantitatively in terms of service speed, accuracy, dependability, security level and price related (performance) measures

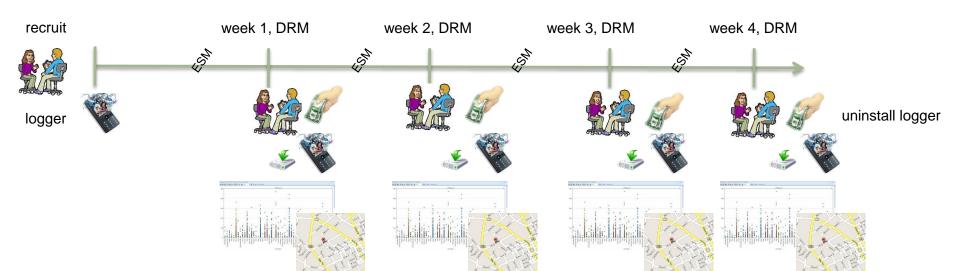
# Goal: User Acceptance



- NO design guidelines for QoE assurance "in the wild" [Kjeldskov, 2003; Hornbaek, 2006]
- Gap between QoE and QoS in mobile service delivery
  - Human Computer Interaction (HCI): Methods for usability evaluation
  - Networking: Evaluation of QoS and network performance
- Our Approach: Evaluate QoE "in the wild"
  - sample QoE on user phones, for their applications, in their environments
    - → indicate factors influencing QoE, amongst others, related to QoS

### User Study: Methods Overview

- Mixed method
  - Qualitative methods
    - First: Initial Interview
    - Daily: Experience Sampling Method [Larson and Csikszentmihalyi, 1983; Hektner et al, 2006]
    - Weekly: Day Reconstruction Method [Kahneman et al, 2006]
  - Quantitative methods
    - Smartphone logger (continuous, automatic, unobtrusive) [Dey, Wac et al., 2011]



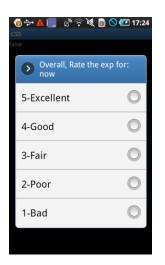
### Methods (I)

#### Initial Interview

- Since when use of mobile, what phone(s) & provider
- What applications used, what wished to be used
- Phone use (SMS, calls)
- Phone proximity at day-night, week-weekend, home-outside, etc.
- Battery lifetime, current/wished for, charging patterns
- Overall experience (and why so) and expectations not yet met
- Age, education, occupation, marital status, cultural background, etc.
- + Any other comments

### Methods (II)

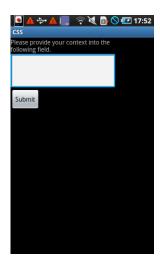
- ESM: Event-contingent (after app use) or self-initiated (while using the app
  - Mean Opinion Score [ITU-R, 2003]











# Methods (III)

- Day Reconstruction Method
  - Affinity clustering of data into themes
  - Two coders

Time	Mobile Phone Usage	Your Experience	Your Location and context	
11:30 AM			meeling	
12:00 PM			6	
12:30 PM	F & Tempil wet		1/2 real port	
1:00 PM	texting '		class	
1:30 PM			000033	
2:00 PM	crasquist   Ways	11 1	0 0	Crosh
2:30 PM	1 Ways		PITON	
3:00 PM			meeting	
3:30 PM	maps/pe	N.	Triq e Will	
4:00 PM	1 0 0		188	
4:30 PM	93	~	3 \$	
5:00 PM	1 3 3		600	
5:30 PM	14-0		7	
6:00 PM			6,20	
6:30 PM			2 /2 m	1 16
7:00 PM			- 0	
7:30 PM				
8:00 PM			l g	
8:30 PM	Ze /	1	- 3	
9:00 PM	18 m	100	3	
9:30 PM	C 500	5	0	1 19
10:00 PM				
10:30 PM				
11:00 PM				4
11:30 PM				

[Kahneman et al, 2006]

### Methods (IV)

- Smartphone logger: Context Sensing Software (min Android 2.1.1)
  - Location (lat, long, bearing, alt, speed, accuracy) GPS or network-based
  - Applications: active, inactive, background processes, CPU/memory usage
  - Cell network radio technology (2.5G/3G/4G), operator, CellID, RSSI, neighbor cells, if roaming
  - WiFi active/inactive, Access Point (AP), RSSI, neighbor APs
  - IP address, active interface (cell or WiFi)
  - Throughput: received/send in Bytes/s
  - Interactive delays: fetching the weather from the web server (HTTP-SRT), ping value (RTT)
  - Battery level, charging (USB/AC), temperature, health, uptime
  - Screen on/off, locked/unlocked, brightness, orientation, ambient light
  - Voice calls, SMS/MMS activity
  - Accelerometer, magnetometer, gyroscope

WatchDog: restart process if killed, KeepAlive every 5 min, email user if not "alive" for 30 min

# QoS

#### Study Participants

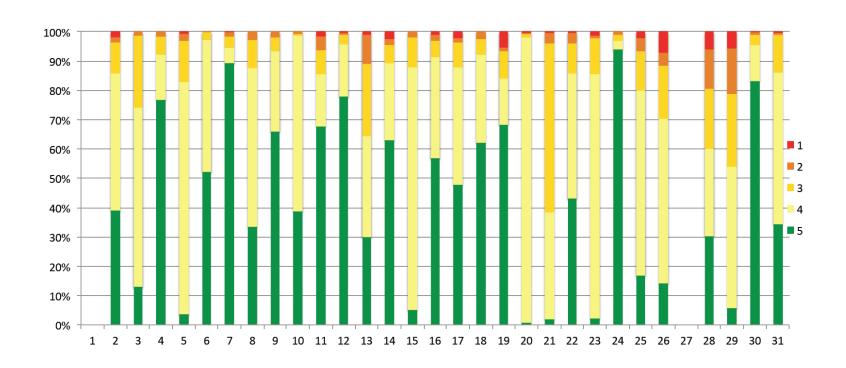
- 31 recruited, 2 drop out
  - Internet advertisement (craiglist Pittsburgh), compensated \$105-145
  - 18-45 years old; 9 females, 21 males
  - Diverse occupations
    - Paramedic, nanny, truck driver, nurse, teacher, student, ...
  - Own phones
    - Motorola Droid {X, 2}, Droid Incredible, My Touch, HTC Evo 4G
  - Verizon (23), Sprint (4), T-mobile (2), AT&T (1) (unlimited data plan)
- Data Collected
  - 17'699 h (87.8% time)
    - One subject switching off phone (teacher)
  - 7804 ratings, 9.29 ratings/day/participants

#### **Top Applications**

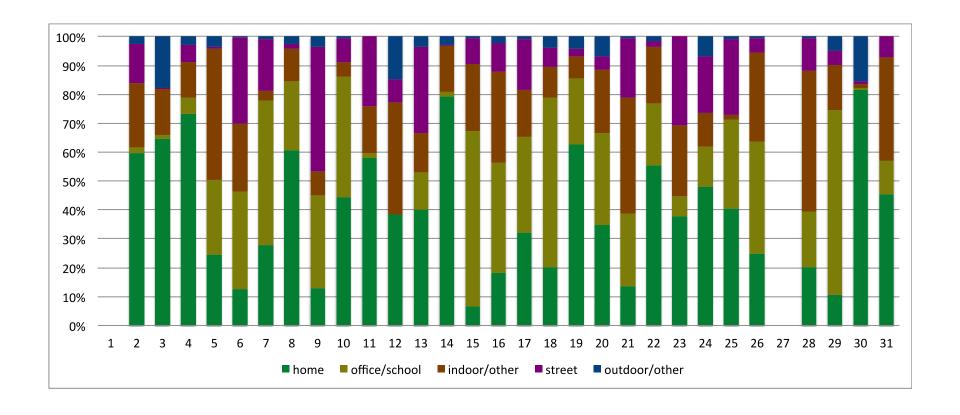
- Communication
  - gmail, email, skype, gtalk, talk, ...
- Web
  - browser, dolphin
- Social network
  - foursquare, facebook, twitter, ...
- Productivity
  - astrid, sandbox, calendar, outofmilk,
- Weather
  - weather, weather service, ...
- News
  - espn, sports, foxnews, pittFight, ...

- Multimedia streaming
  - listen, pandora, youtube, lastfm, ...
- Games
  - worldwar, WoW, poker, zyngawords,...
- Lifestyle
  - horoscope, sparkpeople, diet, ...
- Finances
  - stock, ...
- Shopping
  - ebay, coupons, starbucks, ...
- Travel
  - navigator, maps, ...
- Others

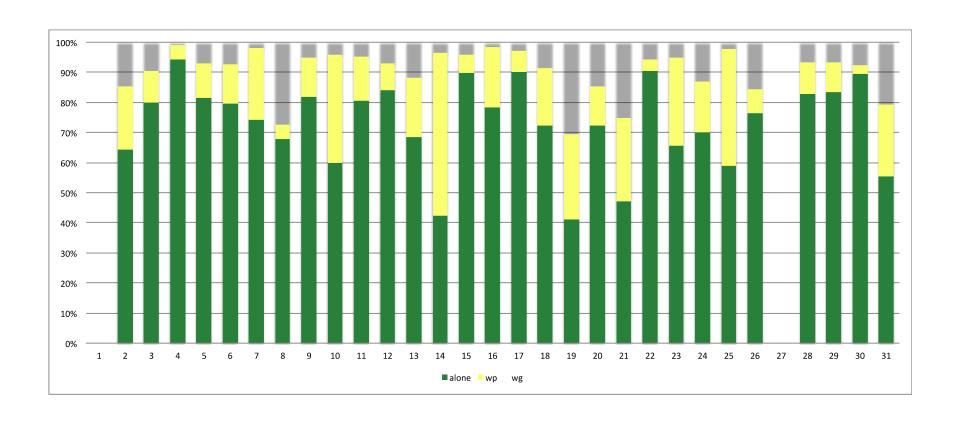
# **MOS** Ratings



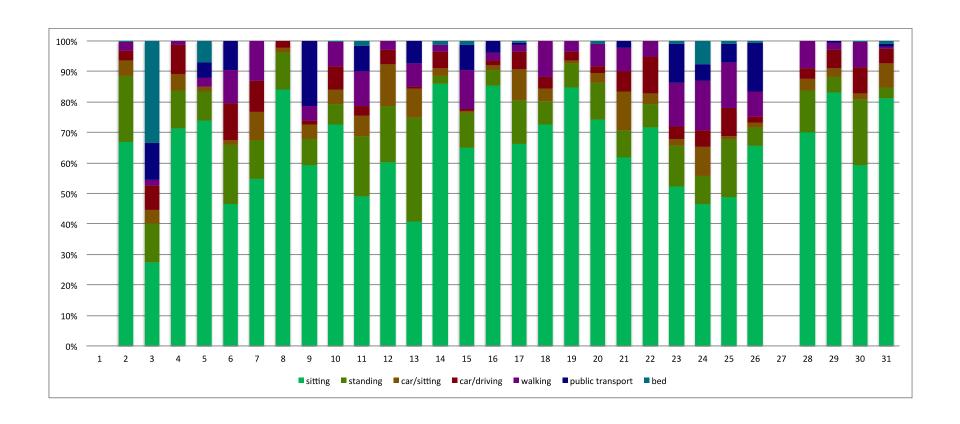
#### Location



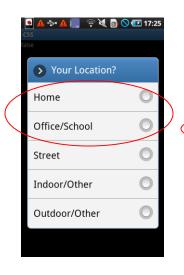
# **Social Context**

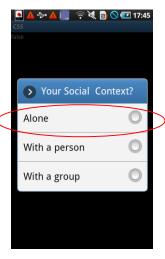


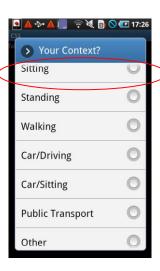
# Mobility

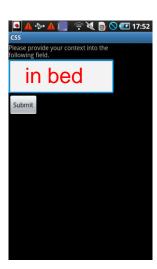


# Most Frequent Context

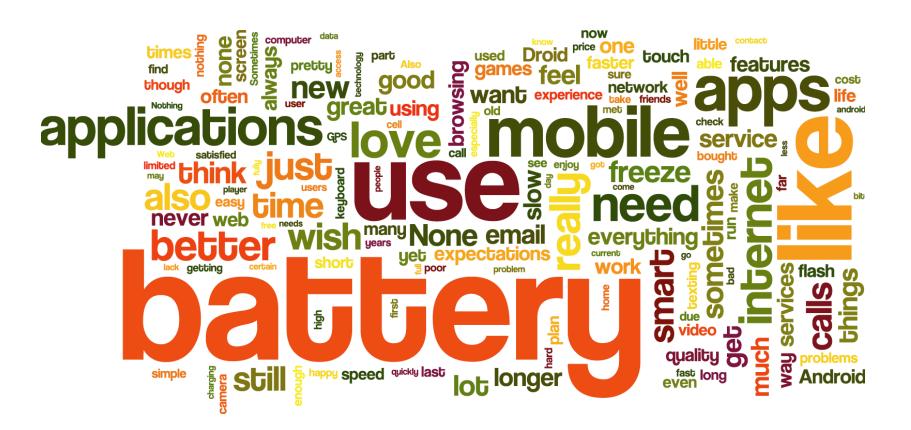








#### What Influences QoE?



### What Influences QoE? (I)

#### Battery

Lower experience, especially if less than one day

#### Application Interface Design

- Position & location of the keys
- Scrolling and resizing
- Inefficient input for 'fat finger' problem
- Web-interface preferred over widget

#### Application Performance

- 'Freeze', 'sloppy', 'sluggish', 'speed', 'crash', 'performance', 'slow', 'force close'
- Web-interface faster than widget
- PC-based interface faster than smartphone, e.g., for writing emails
- QoE & QoS: "skyping service is incredible spotty"

# What Influences QoE? (II)

#### Phone Features

- No flash player
- Inaccurate GPS
- No advanced settings, e.g., personalized alarm clock, security

#### Routine

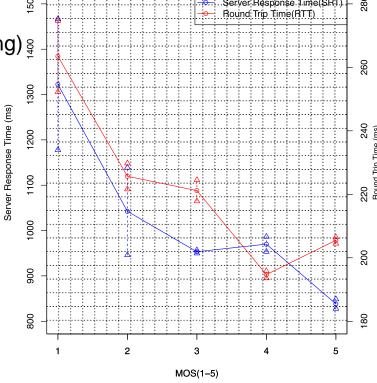
- Locations, times and app purpose/criticality for the user's goal
- Lifestyle Needs
  - Concrete goal in concrete context, e.g., at the gym

#### The role of QoS (I)

- Wireless access technology (2.5G-4G)
  - Well-connected: GPRS, 1xRTT, CDMA, EDGE, UMTS, EVDO<sub>0</sub>, EVDO<sub>4</sub>, HSPA, WiMAX
  - WiFi at home & office (50% of users), 9 always OFF, 6 always ON

Delays (SRT for HTTP request and RTT for ping) §

? MOS 3 for 950ms



### The role of QoS (II)

- Worst QoE for streaming multimedia
  - Avg. 1.67h/day ∠1.38GB ¬0.5GB (top 10 users)
  - Top daily



'listen' 0.8h

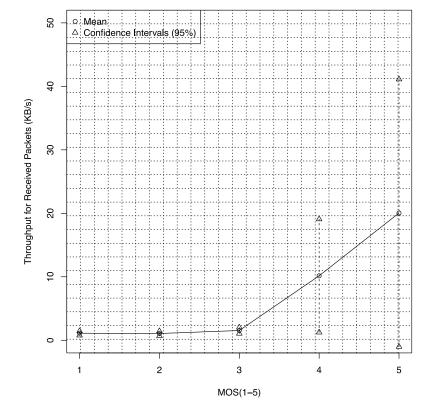
'pandora' 0.5h

'youtube' 0.34h

**∠**32.7MB **⊅**1.03MB

**∠**8.15MB **⊅**0.3MB

**∠**8.36MB **⊅**0.36MB



# The role of QoS (III)

#### 4G-WiMAX

- possible to be used by 3 participants but mostly unavailable
- "unfortunately, I don't get 4G in (A). And when I'm in (B), the 4G connection keeps switching on and off, and the notifications (which are similar to the notification for Wireless Fidelity (WiFi) connections) are just annoying. So I keep 4G switched off" (S18)
- "My phone can operate on a 4G network, but I usually keep it set to 3G because in my experience, the 4G is not considerably faster and just eats up my battery.
  - ... Generally I keep 4G turned off unless I am doing something network intensive and I know it is available" (S20)
- usage of 4G depends on willingness of charging: from 3G-WiFi-4G to WiFi/4G-3G

#### **Conclusive Remarks**

- Explorative study
  - Indicate factors influencing QoE, amongst others, related to QoS
- Limitations
  - Internal validity (correlation vs causality)
  - Self-selective participants, self-selective phones and applications
  - Limited time, limited number of participants
- Future Work
  - "Worst case QoS"
  - Statistical significance of variables → grounded theory [Martin 1986; Karnenburg 2005]
  - Implications for mobile applications design
  - QoE assurance strategies, by predicting QoE "in the wild"

#### Questions?



