

# **Evaluating the Accuracy of Data Collection on Mobile Phones: A Study of Forms, SMS, and Voice**

Somani Patnaik<sup>1</sup>, Emma Brunskill<sup>1</sup>, William Thies<sup>2</sup>

---

<sup>1</sup> Massachusetts Institute of Technology

<sup>2</sup> Microsoft Research India

# Mobile Data Collection is in Style

- **Especially in the developing world**

- Mobile banking
- Microfinance
- Healthcare
- Environmental monitoring



**MOSNEWS.COM**

## Russia to introduce mobile phone voting in 2011

9 Apr, 03:38 PM

At the 2011 parliamentary elections, Russians will be able to cast their votes via their mobile phones, the Central Elections Commission has said.

- **Benefits:**

- Faster
- Cheaper
- More accurate

**No prior study of entry accuracy**  
(on low-cost phones in developing world)

# Data Collection on Mobile Phones

OpenROSA

FrontlineSMS Forms [[Banks](#)]

Nokia Data Gathering [[Nokia](#)]

RapidSMS [[UNICEF](#)]

MobileResearcher [[Populi.net](#)]

Cell-Life in South Africa [[Fynn](#)]

Jiva TeleDoc in India [[UN Publications](#)]

Pesinet in Mali [[Balancing Act News](#)]

Malaria monitoring in Kenya [[Nokia News](#)]

Voxiva Cell-PREVEN in Peru [[Curioso et. al](#)]

## Data Collection on Mobile Phones

OpenROSA

FrontlineSMS Forms [[Banks](#)]

Nokia Data Gathering [[Nokia](#)]

RapidSMS [[UNICEF](#)]

MobileResearcher [[Populi.net](#)]

Cell-Life in South Africa [[Fynn](#)]

Jiva TeleDoc in India [[UN Publications](#)]

Pesinet in Mali [[Balancing Act News](#)]

Malaria monitoring in Kenya [[Nokia News](#)]

Voxiva Cell-PREVEN in Peru [[Curioso et. al](#)]

## Data Collection on PDAs

SATELLIFE

EpiHandy

EpiSurveyor [[Datadyne](#)]

Infant health in Tanzania [[Shrima et al.](#)]

e-IMCI in Tanzania [[DeRenzi et al.](#)]

Respiratory health in Kenya [[Diero et al.](#)]

Tobacco survey in India [[Gupta](#)]

Ca:sh in India [[Anantramanan et al.](#)]

Malaria monitoring in Gambia [[Forster et al.](#)]

Clinical study in Gabon [[Missinou et al.](#)]

Tuberculosis records in Peru [[Blaya et al.](#)]

Sexual surveys in Peru [[Bernabe-Ortiz et al.](#)]

## Data Collection on Mobile Phones

OpenROSA

FrontlineSMS Forms [\[Banks\]](#)

Nokia Data Gathering [\[Nokia\]](#)

RapidSMS [\[UNICEF\]](#)

MobileResearcher [\[Populi.net\]](#)

Cell-Life in South Africa [\[Fynn\]](#)

Jiva TeleDoc in India [\[UN Publications\]](#)

Pesinet in Mali [\[Balancing Act News\]](#)

Malaria monitoring in Kenya [\[Nokia News\]](#)

Voxiva Cell-PREVEN in Peru [\[Curioso et. al\]](#)

## Data Collection on PDAs

SATELLIFE

EpiHandy

EpiSurveyor [\[Datadyne\]](#)

Infant health in Tanzania [\[Shrima et al.\]](#)

e-IMCI in Tanzania [\[DeRenzi et al.\]](#)

Respiratory health in Kenya [\[Diero et al.\]](#)

Tobacco survey in India [\[Gupta\]](#)

Ca:sh in India [\[Anantramanan et al.\]](#)

---

## Published Error Rates

Malaria monitoring in Gambia [\[Forster et al.\]](#)

Clinical study in Gabon [\[Missinou et al.\]](#)

Tuberculosis records in Peru [\[Blaya et al.\]](#)

Sexual surveys in Peru [\[Bernabe-Ortiz et al.\]](#)

## Data Collection on Mobile Phones

OpenROSA

FrontlineSMS Forms [\[Banks\]](#)

Nokia Data Gathering [\[Nokia\]](#)

RapidSMS [\[UNICEF\]](#)

MobileResearcher [\[Populi.net\]](#)

Cell-Life in South Africa [\[Fynn\]](#)

Jiva TeleDoc in India [\[UN Publications\]](#)

Pesinet in Mali [\[Balancing Act News\]](#)

Malaria monitoring in Kenya [\[Nokia News\]](#)

Voxiva Cell-PREVEN in Peru [\[Curioso et. al\]](#)

## Data Collection on PDAs

SATELLIFE

EpiHandy

EpiSurveyor [\[Datadyne\]](#)

Infant health in Tanzania [\[Shrima et al.\]](#)

e-IMCI in Tanzania [\[DeRenzi et al.\]](#)

Respiratory health in Kenya [\[Diero et al.\]](#)

Tobacco survey in India [\[Gupta\]](#)

Ca:sh in India [\[Anantramanan et al.\]](#)

---

## Published Error Rates

*None?*

CAM in India [\[Parikh et al.\]](#)

## Published Error Rates

Malaria monitoring in Gambia [\[Forster et al.\]](#)

Clinical study in Gabon [\[Missinou et al.\]](#)

Tuberculosis records in Peru [\[Blaya et al.\]](#)

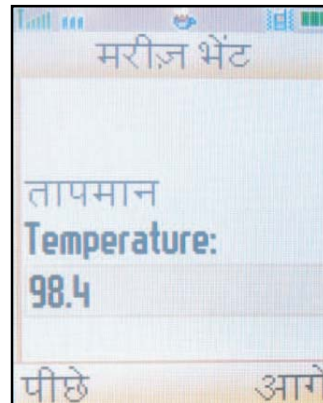
Sexual surveys in Peru [\[Bernabe-Ortiz et al.\]](#)

# Our Study

- Compared three interfaces for health data collection

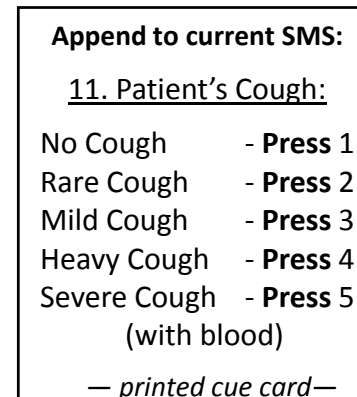
*13 literate health workers & hospital staff, Gujarat, India*

## Electronic Forms



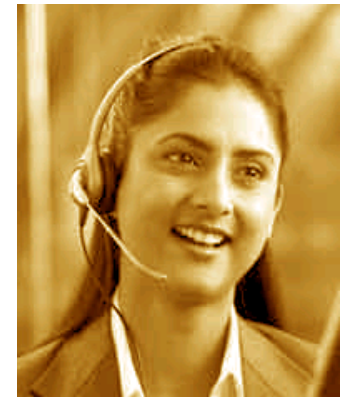
**Error rate: 4.2%**

## SMS



**4.5%**

## Live Operator



**0.45%**

**Result caused partners to switch from forms to operator**

- **Recommendations:**

1. Caution needed in deploying critical apps w/ non-expert users
2. A live operator can be accurate and cost-effective solution

# Context: Rural Tuberculosis Treatment

- **With local partners, working to improve tuberculosis treatment in rural Bihar, India**

 THE PRAJNOPAYA FOUNDATION  INNOVATORS IN HEALTH



- **Strategy: monitor patient symptoms remotely**



Health worker  
uploads symptoms

Physician reviews,  
advises, schedules visits

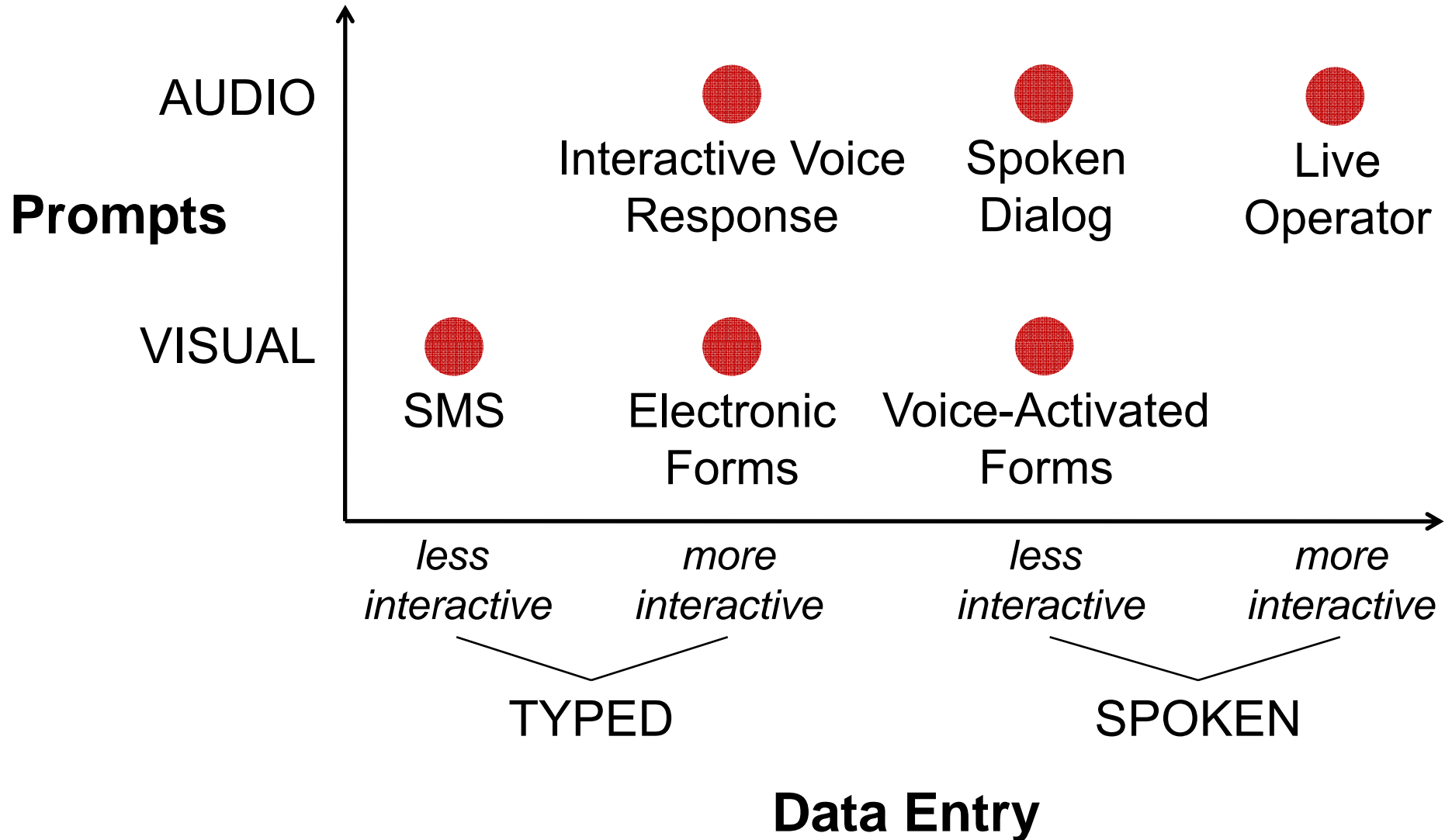


- **Data uploaded: 11 questions, every 2 weeks**

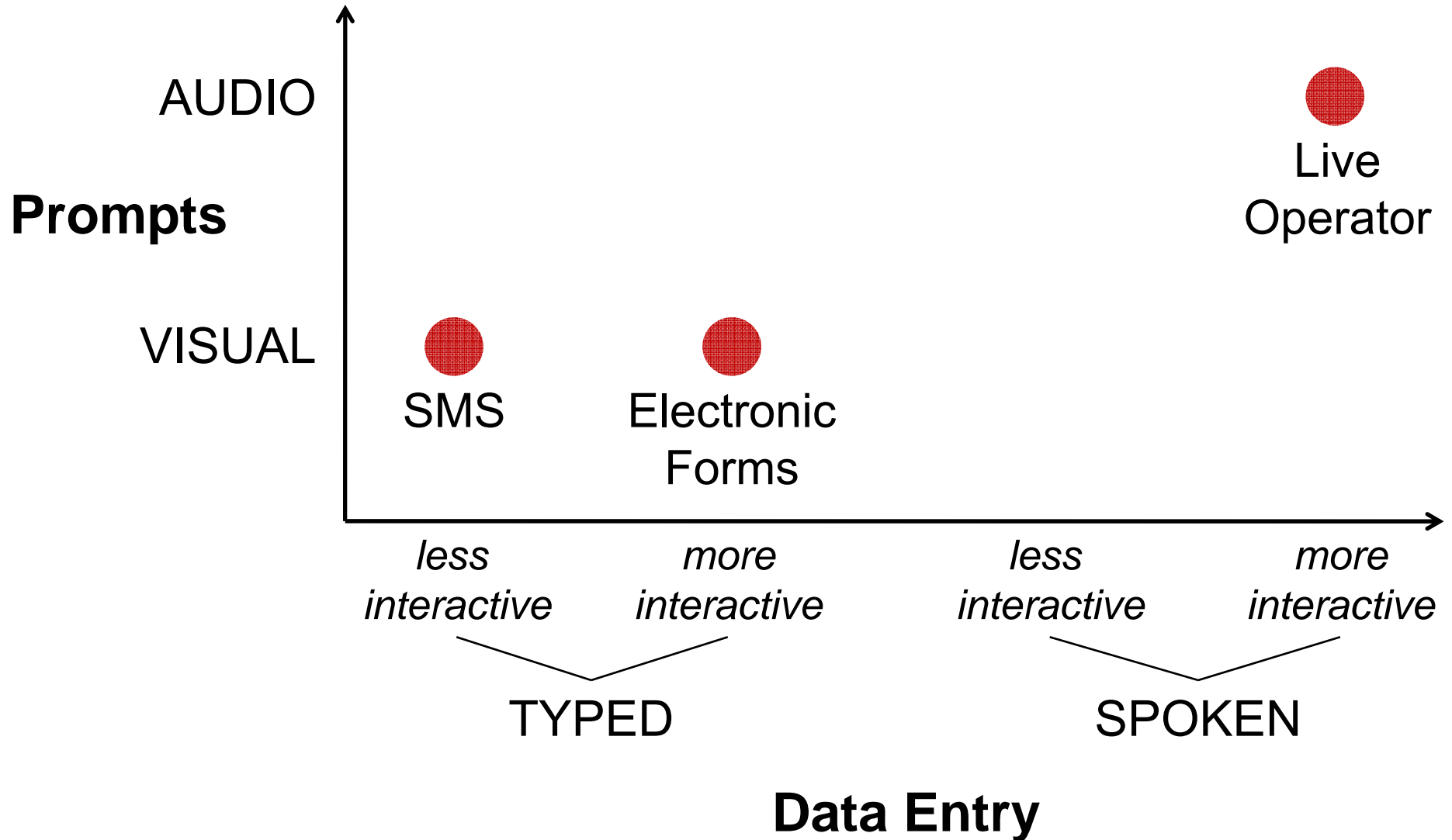
- Patient ID
- Temperature
- Weight
- Cough (multiple choice)
- Symptoms (yes / no)



# Design Space: Data Collection on Low-End Phones



# Design Space: Data Collection on Low-End Phones



# 1. SMS Interface

- **Pro:**
  - + Potentially cheapest
- **Con:**
  - Easiest to fake visits
  - Least reliable

⋮

## 11. Enter the Patient's Cough

No Cough	- Press 1
Rare Cough	- Press 2
Mild Cough	- Press 3
Heavy Cough	- Press 4
Severe Cough (with blood)	- Press 5

⋮

## 21. Check Yourself

Your finished message should be formatted similarly to the following:  
**10 372 62 68 4 1030007**

## 2. Electronic Forms Interface

- **Pro:**
  - + Arguably more user friendly than SMS
- **Con:**
  - Expensive handset



# 3. Live Operator Interface

- **Pro:**
  - + Most flexible Q&A
  - + No literacy required
  - + Hard to fake visits
- **Con:**
  - Cost of operator
  - Potentially slower



# Study Participants

- 13 health workers and hospital staff (Gujarat, India)

	Age (Median)	Education	Cell Phone Experience
Health workers (6)	23	10 <sup>th</sup> – 12 <sup>th</sup>	Had used phone
Hospital staff (7)	30	12 <sup>th</sup> – D. Pharm.	Owned phone

- **Within-subjects design**
- **Training standard:  
two error-free reports  
on each interface**
  - Health workers:  
big groups, 6-8 hours
  - Hospital staff:  
small groups, 1-2 hours



# Results

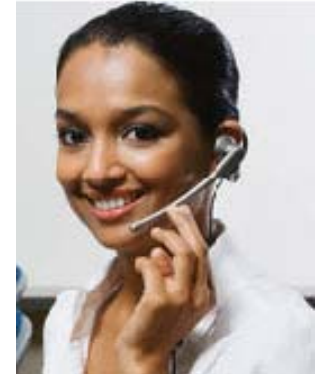


## Append to current SMS:

### 11. Patient's Cough:

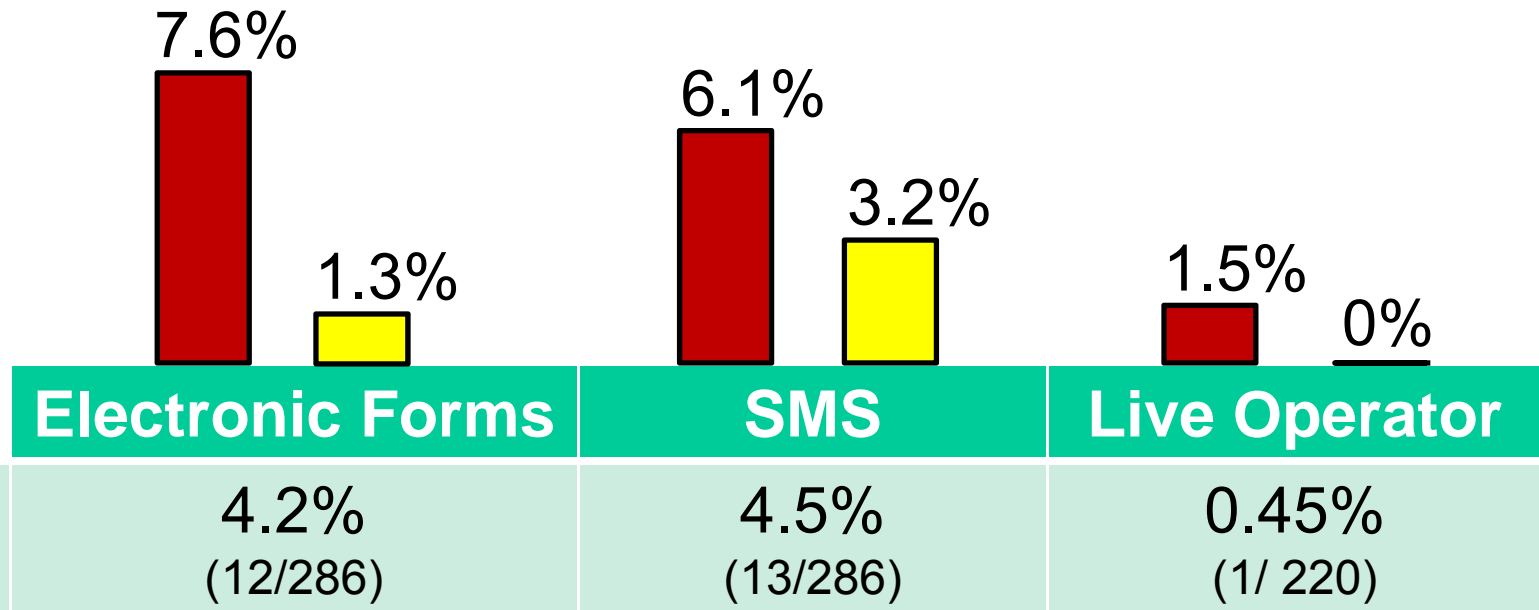
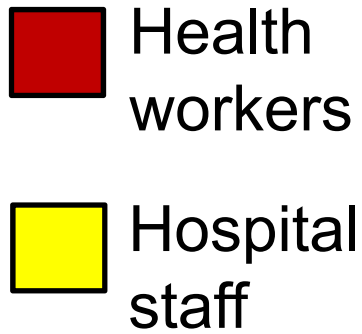
- No Cough - Press 1
- Rare Cough - Press 2
- Mild Cough - Press 3
- Heavy Cough - Press 4
- Severe Cough - Press 5  
(with blood)

— printed cue card—



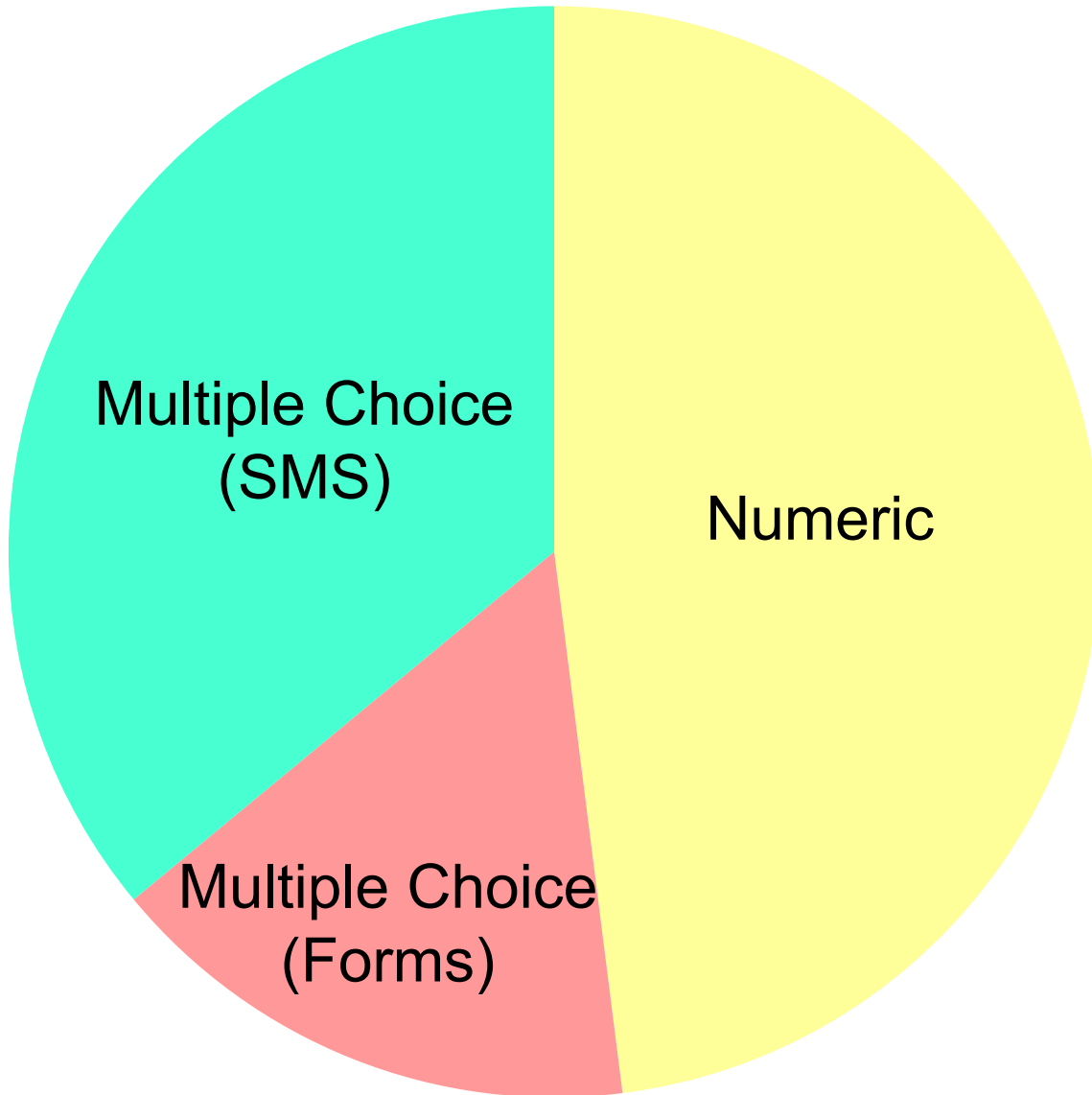
	Electronic Forms	SMS	Live Operator
Error rate (errors / entries)	4.2% (12/286)	4.5% (13/286)	0.45% (1/ 220)

# Results

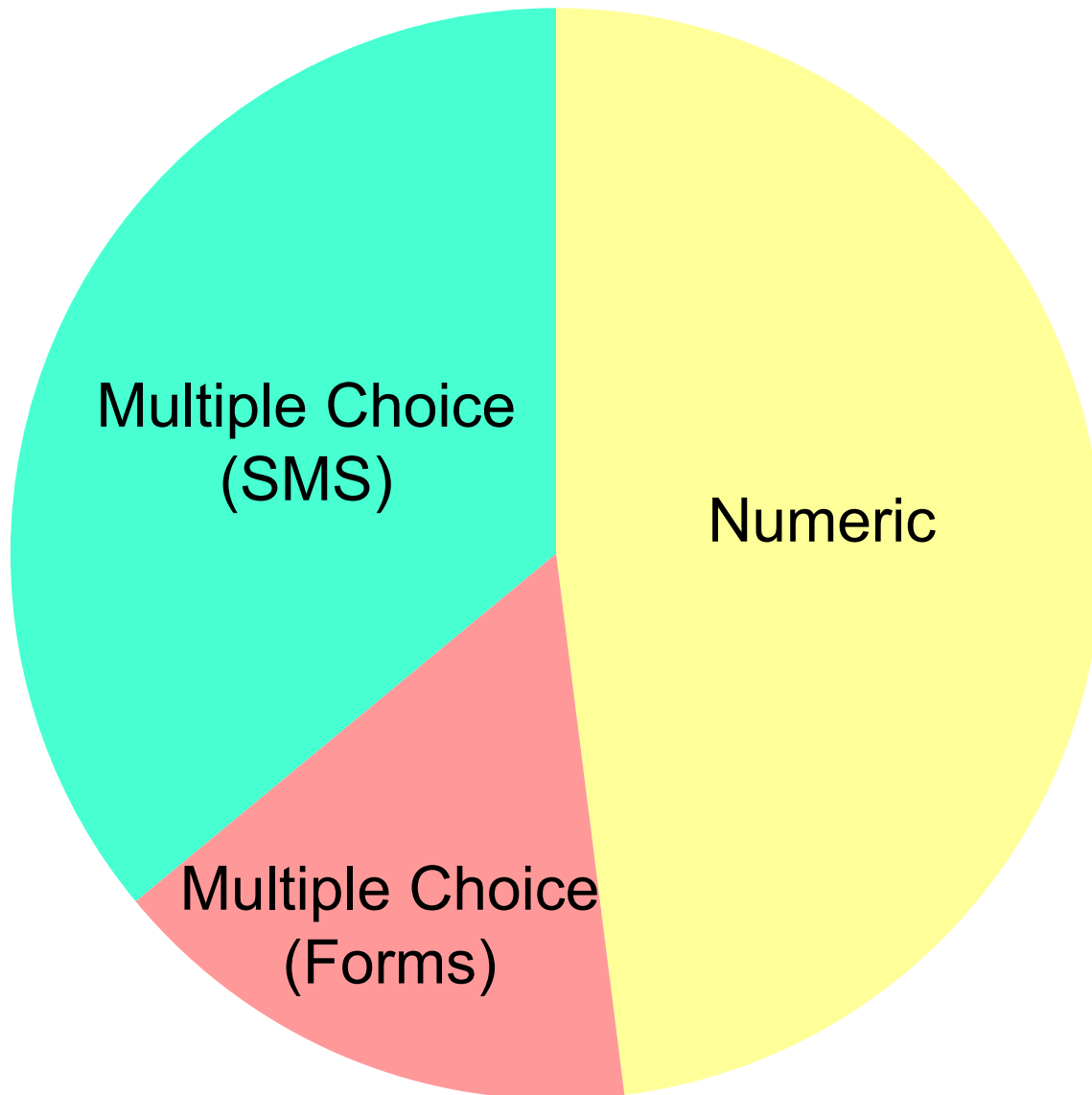




# Sources of Error



# Sources of Error

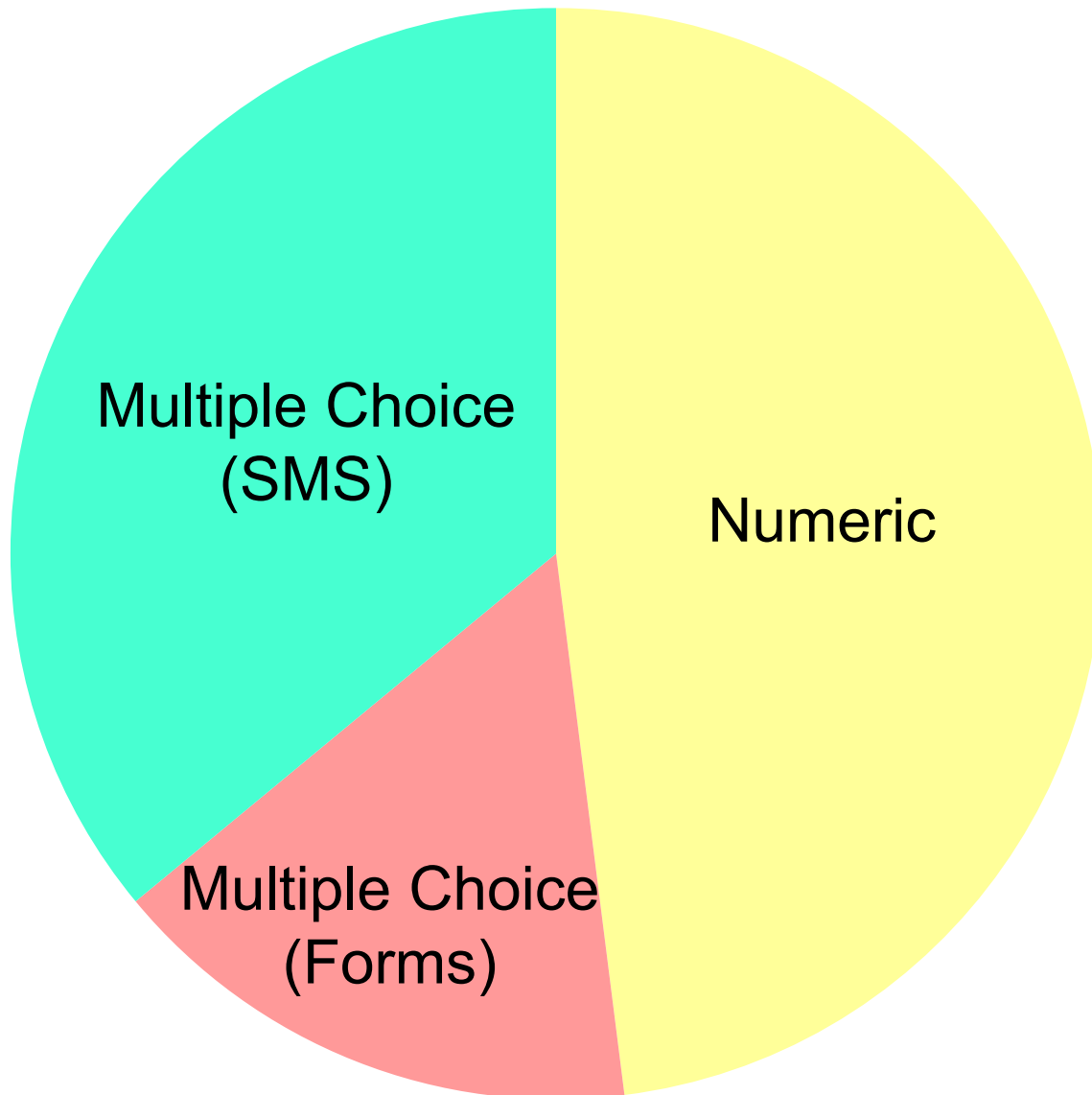


## Usability Barriers

- small keys
- correcting mistakes
- decimal point

Correct	Incorrect
54	45
62	826
62	<i>empty</i>
68	67
68	93
69	59
98.5	98
98.7	98.687
100.2	100.0
100.3	103
“1003”	103
100.8	108

# Sources of Error

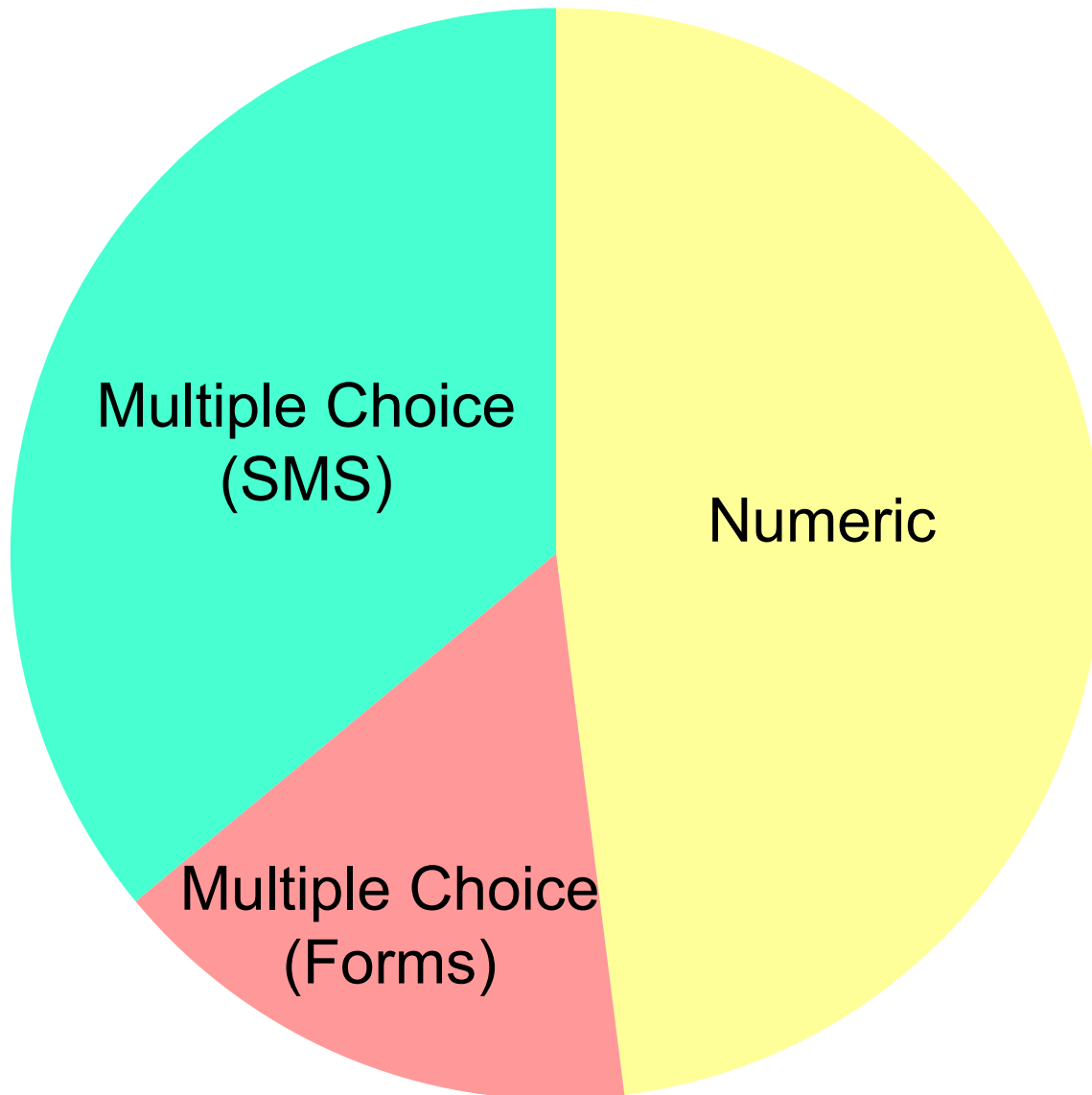


## Usability Barriers

- small keys
- correcting mistakes
- decimal point
- scrolling / selection

Correct	Incorrect
Mild	None
Heavy	Mild
Yes	No
No	Yes

# Sources of Error



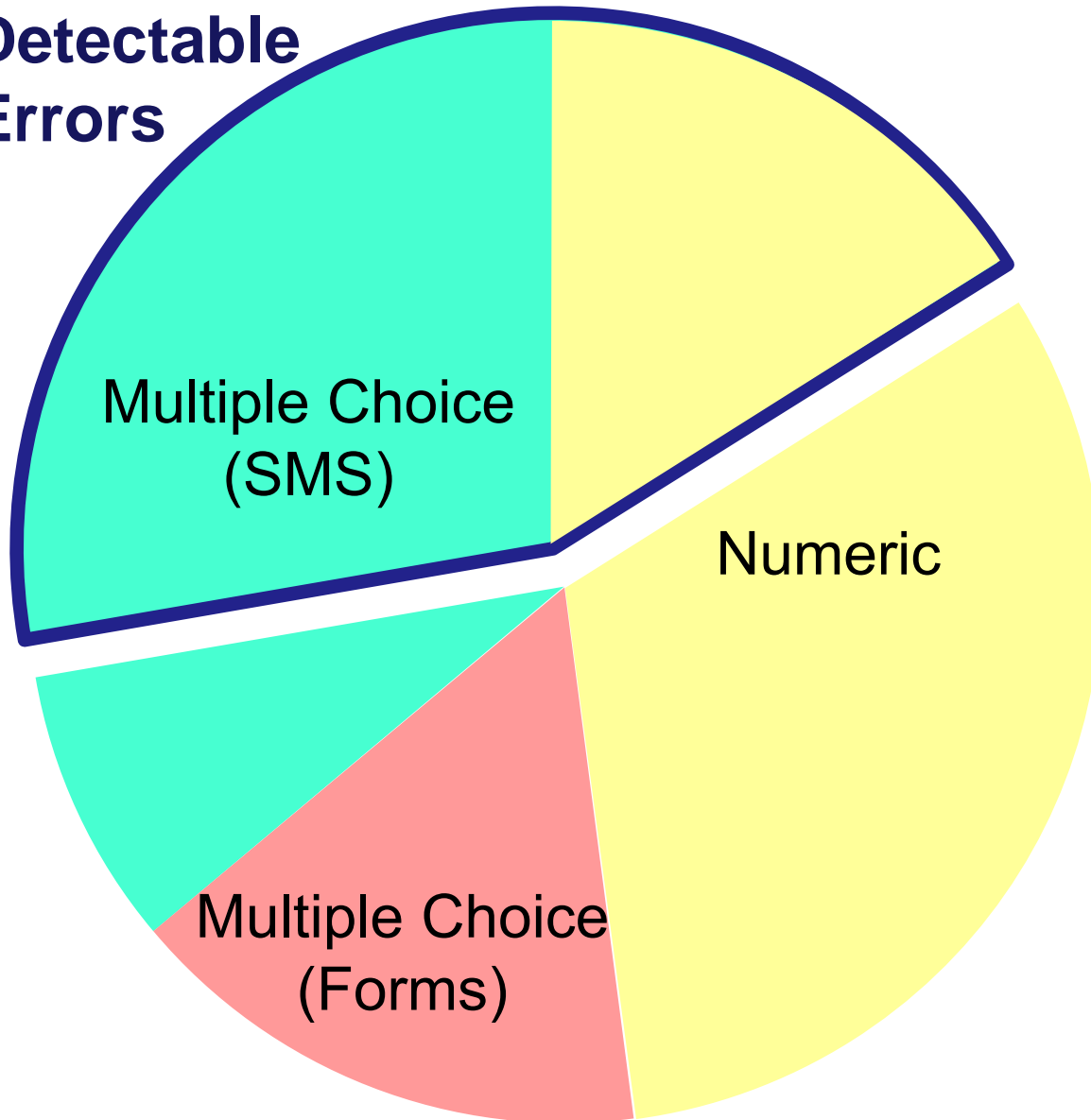
## Usability Barriers

- small keys
- correcting mistakes
- decimal point
- scrolling / selection
- SMS encoding

Correct	Incorrect
"1" (none)	"0" (disallowed)
"1" (none)	"0" (disallowed)
"1" (none)	"0" (disallowed)
"3" (mild)	"0" (disallowed)
"5" (severe)	<i>empty</i>
"6" (A. Khanna)	"5" (A. Kumar)
"7" (A. Kapoor)	"1" (A. Khan)
"6"	"2"
"0000007"	"000007"

# Sources of Error

**Detectable  
Errors**



## Usability Barriers

- small keys
- correcting mistakes
- decimal point
- scrolling / selection
- SMS encoding

# Cost Comparison

	SMS	Forms	Live Operator
Cost per interview	$C_s$	$C_s$	$(C_v + C_o) T$

## Program variables

**T** time spent per interview

## Cost variables

**$C_s$**  cost of an SMS

**$C_v$**  cost of a voice minute

**$C_o$**  cost of an operator minute

# Cost Comparison

	SMS	Forms	Live Operator
Cost per interview	\$0.03	\$0.03	\$0.06 T

## Program variables

**T** time spent per interview

## Cost variables in Bihar, India

**\$0.03** cost of an SMS

**\$0.02** cost of a voice minute

**\$0.04** cost of an operator minute

# Cost Comparison

	SMS	Forms	Live Operator
Cost per interview	\$0.03	\$0.03	\$0.06 T

Break-even call: 30 seconds

## Program variables

**T** time spent per interview

## Cost variables in Bihar, India

**\$0.03** cost of an SMS

**\$0.02** cost of a voice minute

**\$0.04** cost of an operator minute



# Cost Comparison (TB Program)

	SMS	Forms	Live Operator
Cost per interview	\$0.03	\$0.03	\$0.15
Cost per phone	\$25	\$50	\$25
<b>Total cost</b>	<b>\$29</b>	<b>\$54</b>	<b>\$43</b>

SMS < Live Operator < Forms

## Program variables

**2.5 min** time spent per interview  
**120** number of interviews  
 for duration of program

## Cost variables in Bihar, India

**\$0.03** cost of an SMS  
**\$0.02** cost of a voice minute  
**\$0.04** cost of an operator minute

# Cost Comparison (Microfinance)

	SMS	Forms	Live Operator
Cost per interview	\$0.03	\$0.03	\$0.60
Cost per phone	\$25	\$50	\$25
<b>Total cost</b>	<b>\$40</b>	<b>\$65</b>	<b>\$325</b>

Microfinance: Operator is 5x more expensive than Forms

## Program variables

**10 min** time spent per interview  
**500** number of interviews  
 for duration of program

## Cost variables in Bihar, India

**\$0.03** cost of an SMS  
**\$0.02** cost of a voice minute  
**\$0.04** cost of an operator minute

# The Case for Live Operators

- **Our proposition:**  
**Operators are under-utilized for mobile data collection**
- **Benefits:**
  - Lowest error rate
  - Less education and training needed
  - Most flexible interface
- **Challenges:**
  - Servicing multiple callers



# Related Work

- **Personal digital assistants (PDAs) for mobile health**
  - 8+ hours training, educated workers: 0.1% - 1.7% error rates  
[Forster et al., 1991] [Missinou et al., 2005] [Blaya & Fraser, 2006]
  - 2-3 minutes training, uneducated workers: 14% error rate  
[Bernabe-Ortiz et al., 2008]
  - In developed world: mixed results vs. paper forms  
[Lane et al., 2006]
- **Richer interfaces**
  - CAM: <1% error rates via camera phone [Parikh et al.]
  - Speech [Patel et al., 2009] [Sherwani et al. 2009] [Grover et al.] [ ... ]
  - Interfaces for low-literate users [Medhi et al.]

# Conclusions

- **Accuracy of mobile data collection demands attention**
  - We measured 5% error rates for those lacking experience
- **There exist cases where a live operator makes sense**
  - Error rates shrunk to 0.5%
  - Can be cost effective, esp. for short calls or infrequent visits
- **Our study has limitations**
  - Small sample size
  - Varied education, phone experience, training of participants
- **Future work**
  - Distinguish factors responsible for error rates
  - Compare to paper forms, Interactive Voice Response