

# Optimal Government Service Delivery with Constraints

## Evidences from An Agricultural Extension IVR System

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<sup>1</sup>Disclosure: Kremer is a board member of PAD. Reich is a data scientist at CEGA and affiliated with PAD. PAD covers travels and expenses for Sun's field trip.

# Introduction

## Adoption of mobile phones and implications for governments

- Wide adoption of mobile phones allow governments to interact with people in unprecedented ways
  - track and monitor, deliver services, provide information
  - interactions are individualized, regular and at low costs
- Information provisions and service delivery with mobile phone technology  
Examples: *Avaaj Otalo* (India), Digital Green, Cocoa Link (Ghana)
- Impacts of the systems not always positive (Aker et al. 2016)  
Users face many barriers to use the systems

# Introduction

## Case Study: IVR System for Agriculture Information

- Examine one country's interactive voice response (IVR) system;
  - PAD found similar issues in multiple countries
- Find users experience many difficulties using the system;
- Use A/B tests to assess relevance of possible barriers users face.

# Co-Production Problem of Information Acquisition

## Government/Developer's Optimization Problem

- benevolent government maximizes social welfare
- measures of welfare: incomes  $\sim$  engagement with the system
- information acquisitions as a co-production or principle-agent problem
  - developers: quality and accessibility of information
  - users: ability and willingness to acquire information
  - conditioning on users' characteristics, how to design a system that maximizes social welfare?

# Co-Production Problem of Information Acquisition

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  - developers: quality and accessibility of information
  - users: ability and willingness to acquire information
  - conditioning on users' characteristics, how to design a system that maximizes social welfare?
- barriers of information acquisitions with heterogeneous users
  - high time costs and impatience
  - low valuations of information
  - limited cognitive ability
  - lack of trust

## Related Literature

### **ICT and agriculture extension services**

- Cole and Fernando 2017 (mobile based extension service in India); Aker, 2011; Casaburi et al., 2018

### **System design with low literacy audience**

- Lee et al., 2003; Mudliar and Donner, 2015 (CGNet Swara, India); Patel et al., 2015 (AO, India); Grover, Stewart and Lubensky, 2009 (design IVR for low literacy users); Aker et al., 2016

### **Barriers of information acquisition**

- Dohmen et al., 2010 (impatience and cognitive ability); Cole et al. 2013 (trust and insurance); Tanguy, et al., 2014 (aspirations); Bhattacharya, et al., 2017 (patience and public good provision)

- 1 Introduction
- 2 Basics of the IVR System
- 3 Findings on Current Usage
- 4 User's Barriers and System Design

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# Facts about the case study country and system users


## About the country:

- Low income, heavily agricultural African country
- Literacy rate in 2015: 49.1%
- Mobile phone penetration rate in 2016: 43%

## About users of the system:

- Average age 27.8, 9.8% females
- On average 7.5 years of edu., 87.3% can write, 98.7% can dial phones
- 88.6% participating in farming, 68.4% buy farm inputs
- Typical farming practices:
  - Most popular crops: maize, wheat, barley
  - 39.9% plough the land manually
  - 86.5% used chemical fertilizers <sup>2</sup>, 36.6% used pesticides

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<sup>2</sup>The government plays a major role in subsidizing and distributing fertilizers throughout the country. 

# Basics of the IVR System

Interactive Voice Recording (IVR) System developed by a government sponsored agency, first launched in 2014

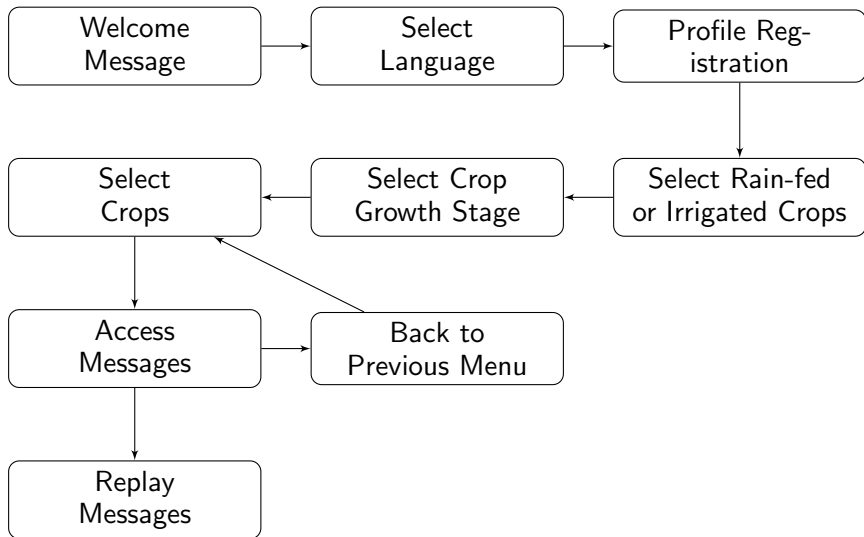
- Access system with toll-free phone calls
- Available nation-wide in multiple languages
- Only requires functioning phones and signals

Agricultural recommendations offered:

- Covers all major cereal crops, cash crops and vegetables
- Covers all stages of growth cycle from land preparation, planting, fertilizer use, to harvesting and storage
- Contents developed and verified by agronomists

Limitation: contents are **NOT** customized

# Using the IVR System: Flow Chart



# Messages in IVR System

## What messages do users access?

“Currently, two sources of nutrients are recommended. **Urea (46% N) and NPS Ammonium Sulfo Phosphate (19% N + 38P2O5+ 7S)**. The recommendation for these nutrient levels vary from place to place and also depending on amount of rainfall. In areas with long history of cultivation, and rainfall above **800mm** during the crop season, most likely the optimum level of fertilizer application will be in the range from **200 to 300 kg/ha of Urea (92-138 kg of N/ha) and 100 kg/ha of NPS** for optimum grain yield.

However, if farmers find these levels to be high and difficult to afford, then **150 kg/ha of Urea and 100 kg/ha of NPS** can be applied with the understanding that grain yield will be somewhat reduced but still attractive provided they use (apply) the inputs efficiently.

In areas where fertilizer recommendation is unknown; **NPS 100kg/ha and Urea 100kg/ha** can be applied. ”

Recommendations involve: 1) technical terms; 2) unfamiliar measurement units; 3) multiple numbers; 4) information for different scenario.

# Descriptions of Dataset

19138234	17366	2018-03-26	09:12:16	Incoming call started	162	fa9e5036-ed3c-431
19138247	17366	2018-03-26	09:12:24	Welcome message played	1	fa9e5036-ed3c-431
19138401	17366	2018-03-26	09:13:24	The application hung up the phone	33	fa9e5036-ed3c-431
19138412	17366	2018-03-26	09:13:29	Incoming call started	162	b9db961d-74e6-4f2
19138430	17366	2018-03-26	09:13:37	Welcome message played	1	b9db961d-74e6-4f2
19138463	17366	2018-03-26	09:13:52	Woreda Menu - Enemor Ener	-1	b9db961d-74e6-4f2
19138486	17366	2018-03-26	09:14:01	Gender Menu - Female option selected	128	b9db961d-74e6-4f2
19138487	17366	2018-03-26	09:14:01	Profile registration complete	137	b9db961d-74e6-4f2
19138525	17366	2018-03-26	09:14:17	Top Menu - Rain option selected	301	b9db961d-74e6-4f2
19138534	17366	2018-03-26	09:14:22	Main Menu - Pre Planting option selected	15	b9db961d-74e6-4f2
19138550	17366	2018-03-26	09:14:28	Menu 1 - Land Preparation option selected	280	b9db961d-74e6-4f2
19138566	17366	2018-03-26	09:14:38	Crop Menu - Maize option selected	35	b9db961d-74e6-4f2
19138634	17366	2018-03-26	09:15:11	Content Played - Land Preparation - Maize - Am...	1000506	b9db961d-74e6-4f2
19138654	17366	2018-03-26	09:15:18	Content Menu - Content information for a diffe...	50	b9db961d-74e6-4f2
19138730	17366	2018-03-26	09:16:04	Crop Menu - Go to Main Menu option selected	42	b9db961d-74e6-4f2
19138753	17366	2018-03-26	09:16:17	Top Menu - Reset Profile option selected	303	b9db961d-74e6-4f2
19138755	17366	2018-03-26	09:16:18	Reset Menu - Reset Menu replayed	352	b9db961d-74e6-4f2
19138766	17366	2018-03-26	09:16:24	Top Menu - HHI option selected	302	b9db961d-74e6-4f2
19138778	17366	2018-03-26	09:16:29	HHI Main Menu - Pre Planting option selected	305	b9db961d-74e6-4f2
19138784	17366	2018-03-26	09:16:32	HHIMenu 1 - HHI Pre-irrigation option selected	325	b9db961d-74e6-4f2

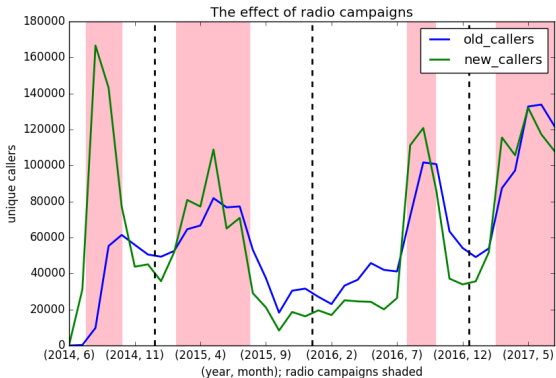
Dataset we have access to:

- call log data recording all events by all callers
  - 3.4 million callers, 272 million events
- supplemental datasets on caller profiles (answers to registration questions)

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# Usage of the System - Recruitment

**Total callers ever called the system: 3.4 million**



- Recruit new users as well as remind old users - old users forgetting about the system without campaigns?

# Usage of the System - Basic Patterns

Table: Summary Statistics At Caller Level

Entry year	2014		2017	
	Mean	Median	Mean	Median
# Calls	9.77	5	6.18	3
# Messages Accessed	11.72	5	5.02	1
# Unique Messages Accessed	9.06	4	3.79	1
# Calls Accessed Messages	4.79	2	2.09	1

Note: analysis based on 50,000 users sample retrieved from the IVR main database in September, 2017, with 10,935 callers entered in 2014 and 14,302 callers entered in 2017 respectively. Unique messages de-duplicated at call level.



## Identify Bottleneck - Funnel Analysis

Funnel analysis helps identify which steps are the bottleneck.

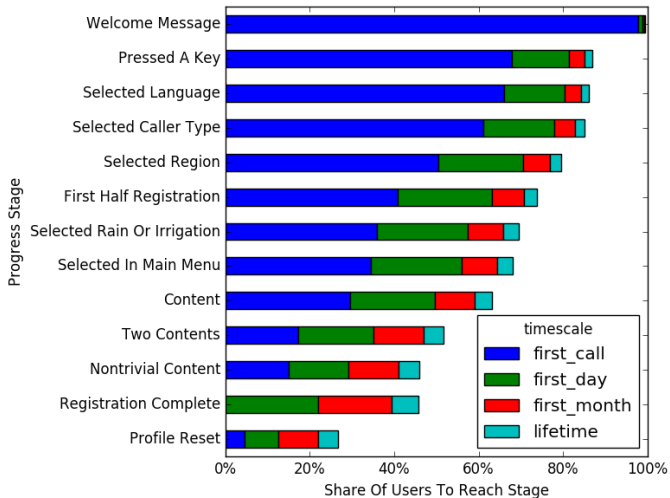
For each step  $k$  during time interval  $t$ , let  $I_{it}^k$  be the indicator for user  $i$  completing step  $k$  within time period  $t$ , and  $N$  be total number of users, then share of users completing the step is given by

$$S_t^k = \frac{1}{N} \sum_i I_{it}^k$$

### Key steps in the system: [Flow Chart](#)

- 1 Welcome Message
- 2 Press A Key
- 3 Selected Language
- 4 Selected Region - Press 2-digits
- 5 Selected Zone
- 6 Selected Rain-fed or Irrigated
- 7 Selected in Crop Growth Stage Menu
- 8 Access Messages

# Identify Bottleneck - Funnel Analysis



# Identify Bottleneck - Funnel Analysis

- Most actions happened in the first day - expanding time interval to first month has little impacts on completing additional steps
- Steps require complicated actions are difficult  
e.g. pressing two-digits keys (select region, district)
- Significant drop at pressing a key step  
⇒ IVR system itself could be confusing
- Many users drop out after profiling question steps during the first call
- Access different messages requires either return to previous menus or hung up and call again  
⇒ navigation back to main menu too complicated

## User Retention

**Simple measure of user retention:** proportion of users continue to call in the system certain time period after they first enter.

Let  $I_{ic}^m$  be an indicator for user  $i$  in cohort  $c$  called the system in  $m$  month after entering the system, then

$$R_c^m = \frac{\sum_i I_{ic}^m}{\sum_i I_{ic}^0}$$

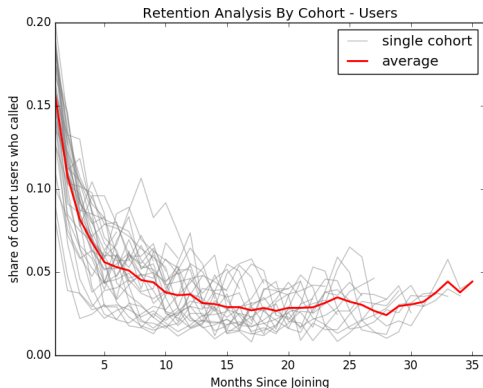
By definition,  $I_{ic}^0 = 1$ , i.e. all users belong to cohort  $c$  actually call in month 0, so  $\sum_i I_{ic}^0$  measures size of cohort  $c$ .

Define average retention rate across cohorts as

$$R^m = \sum_{c=0}^{c=N} \frac{\sum_i I_{ic}^m}{\sum_i I_{ic}^0}$$

where  $N$  is total number of cohorts.

# Users Retention



Low retention rate - only 15% of users continue to call after one month, less than 5% call after 5 months. Initial Experience

Not necessarily bad: users could get all the information they want during the initial month and stop calling.

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# User's Barriers To Acquire Information

## Factors affecting information acquisition:

- time costs\*
- behavioral biases: impatience\*
- valuations of information
- cognitive ability: use IVR system, select language\*
- level of trusts

**Heterogeneity** could be highly relevant for all these barriers

- simple screening mechanisms to categorize users
- provide appropriate information based on users' characteristics

\* indicates A/B tests already implemented.

# Impatience and Time Costs: Profile Registration

**Barrier:** Difficulties encountered during the first calls could deter impatient users and users with high time costs

First time callers need to answer **three** mandatory profiling questions

- Asked at the beginning of the first call
- Questions about occupation and locations
- Location questions require entering two-digit numbers to answer e.g. Press 01 to select XXX region
- Use information collected to send location specific alerts on weather, pest outbreaks, crop diseases, etc.  $\implies$  customization



# Impatience and Time Costs: Profile Registration

- But many answers collected are incorrect
  - share correctly answer region question: 74.8%
  - share correctly answer zone question: 47.6%
  - share correctly answer district question: 16.6%
- Users might not know how to enter right information or they may not want to put in efforts to select right options (select option 1 all the time) Evidences

# A/B Test Results - Removing Profile Registration

**Intervention:** Remove profile registration questions for first time callers, select rain-fed or irrigated crops directly after selecting languages

- Significant effects on engagement with the system

Lang stands for selecting a language, U Mess for unique messages.

	Acc. Mess	# Mess	# U Mess	Lang
Treated	0.0992*** (0.00210)	0.773*** (0.0455)	0.522*** (0.0282)	0.00179 (0.00146)
Obs	210479	210479	210479	210479
Control Mean	.578	4.575	3.1	.869

All regressions include entry date fixed effect.

Robust standard errors in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Caveat: Effects could be mechanical as the system becomes easier to use

# A/B Test Results - Removing Profile Registration

- Lasting significant effects on engagements for subsequent interactions  
U Mess stands for unique messages.

	First Call		First Day		2nd Day and Later	
	Acc. Mess	# Mess	# Mess	# U Mess	# Mess	# U Mess
Treated	0.112*** (0.00203)	0.265*** (0.00688)	0.518*** (0.0161)	0.340*** (0.00986)	0.255*** (0.0383)	0.183*** (0.0238)
Obs	210479	210479	210479	210479	210479	210479
Control Mean	.272	.641	1.746	1.212	2.829	1.888

All regressions include entry date fixed effect.

Robust standard errors in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Funnel Graph

# Heterogeneity: Collect User Information for Customization

**Objective:** collect information from users to send customized alerts with minimal interference on overall user experience

- Screening users according to demands for more customization and ability to follow instructions

## Intervention

- Sample: all callers treated in removing profile registration test
- Ask optional (rather than mandatory) location questions to users after making at least 5 calls or accessed at least 3 messages
- If declines to answer, wait for 5 more calls and ask again
- Explain motivations for asking the questions - provide localized alerts

# Heterogeneity: Collect User Information for Customization

## Caveat:

- Screening out proficient users with demands for information
  - 34% of users reach 5th call, 16% reach 10th call, 9% reach 15th call
  - Average users take 14, 19 and 22 days (median user 6, 11 and 15 days) to make 5, 10 and 15 calls
  - 44% of users listen to 3 or more messages, 27% listen to 6 or more, 18% listen to 9 or more
  - Average user takes 4, 7 and 10 days (median user 0, 1 and 2 days) to listen 3, 6 and 9 messages
- *Imprecise verification for answer correctness*: compare distribution of responses, check if there are fewer selections of option 1

# Valuations and Aspiration: Story from Fellow Farmers

**Barrier:** Users have low valuations of potential benefits and are not motivated to overcome difficulties

**Objective:** motivate usage of the system by making benefits tangible

- More incentives for users who are uncertain about potential benefits of the system or have low valuations of information the system offers
- Could be distracting for non-farmer users
- How important are aspirations from peers? (Tanguy, et al., 2014)

## Intervention

- Replace current welcome message by an aspirational story by a farmer benefited from the system

# Cognitive Ability: IVR Tutorial

**Barrier:** Users are unfamiliar with IVR system and may have difficulty following instructions

**Objective:** help users get familiar with the technology

- Help users overcome some technical barriers to use the system
- Might be less effective if users have difficulty following instructions

## Intervention

- Include a short tutorial on how to navigate the IVR system (interact with the system by pressing buttons) and tips for system use
- Allow users to skip the tutorial by pressing difficult options (e.g. "To skip the tutorial, press 9")

## Cognitive Ability: Language Selection

**Barrier:** Being able to select a proper language defines the minimal threshold for using the system - hard without opportunity to make mistakes

- First time caller asked to select language immediately following welcome message
- Language selection is done once only, at the very start
- Can change language selection if access profile reset menu  
⇒ hard to find if wrong language selected
- Could be very difficult without opportunities for trial-and-errors
- About 14% of users failed to select the language they actually speak - “language bear trap”

**Alternative setup:** ask users to select language for their first few calls

**Current interventions:** tweaks in language menu to help make selections



## A/B Test Results - Replay Language Menu

**Intervention:** replay the language menu once more if no option is selected (current wait before replay is 10 sec)

- Treatment encourages language selection and subsequent access to messages  
Lang stand for selecting a language.

	First Call		First Day		All	
	Lang	Acc. Mess	Lang	Acc. Mess	Acc. Mess	# Mess
Treated	0.0492*** (0.00407)	0.0430*** (0.00372)	0.00778** (0.00294)	0.0136** (0.00415)	0.0125*** (0.00362)	0.0239 (0.138)
Obs	56631	56631	56631	56631	56631	56631
Control Mean	.601	.247	.853	.572	.748	10.022

All regressions include entry date fixed effect.

Robust standard errors in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# A/B Test Results - Add Pauses Between Options

**Intervention:** add 2 seconds gap in between language menu options for treated new users

**Findings:** No effects on language selection nor subsequent engagement  
Lang stand for selecting a language

	First Call		First Day		All	
	Lang	Acc. Mess	Lang	Acc. Mess	Acc. Mess	# Mess
Treated	-0.00199 (0.00203)	0.00236 (0.00205)	-0.00262 (0.00164)	-0.00119 (0.00218)	-0.00206 (0.00211)	-0.0830 (0.0456)
Obs	210444	210465	210465	210465	210465	210465
Control Mean	.686	.327	.829	.526	.628	5.004

All regressions include entry date fixed effect.

Robust standard errors in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# Trust: Introduce Information Sources

**Barrier:** Users may not trust information provided by unknown sources via mobile phones

**Objective:** establish trusts

- Lack of trust for information delivered via mobile phones (as opposed to traditional extension agents)
- Lack of trust for information from unknown sources without recognition by authorities

## Intervention

- Explicitly cite the government or ministry of agriculture as developers of recommendations in welcome message
- Replace welcome messages with a statement or testimony by a development agent or an agronomist

# Conclusions

## Summaries of findings

- Current system is not user friendly: share of users accessing messages low with few messages accessed, low retention, etc.
- Users face substantial barriers using the system yet current design of the system fails to factor in many of the barriers: low cognitive ability, impatience, etc.

## Information Delivery as A Constrained Optimization Problem

- Professional developers (e.g. agronomists) fail to incorporate barriers users might face when design the system;
- Mis-understandings more likely than rent extraction;
- With heterogeneous users one-size-fit-all solution might not work.

# Initial Experience Correlates with Retention

<i>Dep. Var.</i>	Log (Days in the System)	
	First Call	First Day
Progress Index	0.0379*** (0.00316)	0.0848*** (0.00308)
Entry Year FE	Y	Y
Event Year FE	Y	Y
Observations	49,391	49,391
R-squared	0.084	0.094

Robust standard errors in parentheses

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

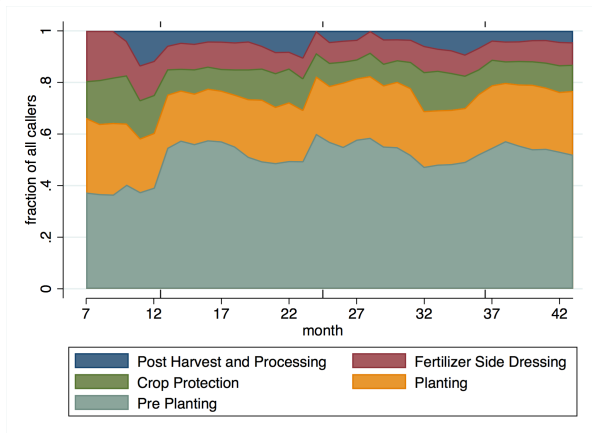
**Progress Index:** on a scale of 0 to 10, 1 = press any keys, 2 = select language, 3 = select occupation, 4 = select region, 5 = select zone, 6 = select in top menu, 7 = select in main menu, 8 = access messages, 9 = access 2 unique messages, 10 = access messages not on land preparation

Making more progress during the first call or the first day correlates with staying in the system longer

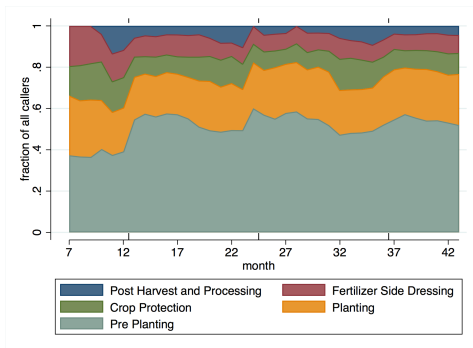
[Back](#)

# Usage of the System - Messages Accessed

Expect to find seasonal variations for messages accessed that co-moves with farming season



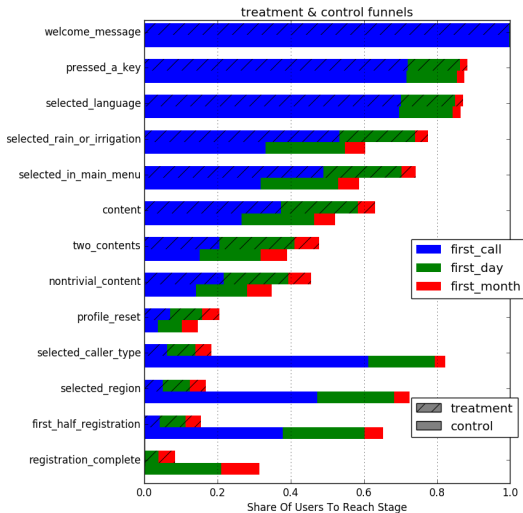
# Usage of the System - Messages Accessed



But no patterns of seasonality in message accessed, pre-planting (land preparation) constantly make up about 40% of message accessed.

Land preparation corresponds to option 1 in crop growth stage menu.

# Funnel Analysis for Removing Profile Registration





## Lack of Efforts or Simply Do not Know?

If users lack efforts to answer profiling questions correctly, then should see:

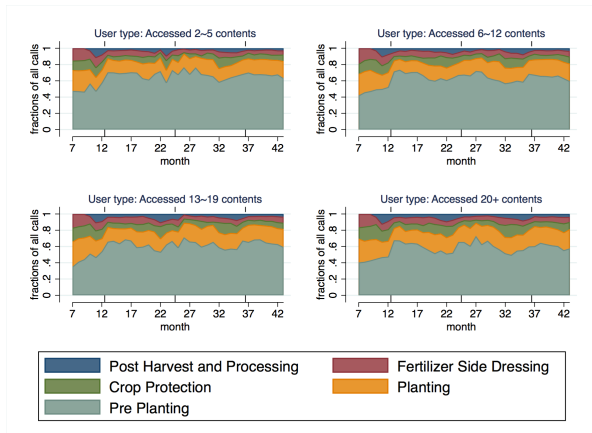
- press 1 all the time for low stake questions (e.g. profiling)
- vary selections according to needs for relevant questions (e.g. language, production stage menu, crop menu)

Evidences **against** lack of efforts:

- share select option 1 for language: 55.28%  
share of population actually speak option 1 language: 21.63%
- share select option 1 for region question: 27.13%  
share of population actually live in option 1 region: 14.55%

⇒ Higher share of callers pressing 1 for language and region selection but language is a high stake question that should be correctly answered.

# Lack of Efforts or Simply Do not Know?



For planting stage selection (high stake question), should **not** press 1 all the time for land preparation (information almost irrelevant for later growing and harvesting seasons) [Back](#)