Information and communication technologies (ICTs) to provide agricultural advice to smallholder farmers: Experimental evidence from Uganda

September 16, 2019

Abstract

Agricultural advisory services generally rely on interpersonal knowledge transfer in which agricultural extension agents visit farmers individually or in groups to provide information and advice. This approach is not always effective and has often proved hard to bring to scale, particularly in highly dispersed smallholder farming systems. Information and communication technologies (ICTs) have been advanced as a promising way to overcome many of the problems associated with conventional agricultural extension. We evaluate the effectiveness of an ICT-mediated approach to deliver agricultural information in a field experiment conducted among small-scale maize farmers in eastern Uganda. Our approach consists of three complementary technologies: First, we investigate the effectiveness of audiovisual messages as a means of delivering information to farmers. Second, we quantify the additional impact of augmenting video with interactive voice response (IVR) technology. Third, we estimate the incremental effect of time-sensitive short message services (SMS) messages that remind farmers about key agronomic practices. We find that ICT-mediated audiovisual content is effective in delivering information, with households that were shown short videos on how to become a

better maize farmer performing significantly better on a knowledge test, more likely to apply recommended practices, and using inputs more efficiently than households that did not see this video. These same households also reported maize yields about 10.5 percent higher than those that did not see the video. Very few of the farmers that were invited to use the IVR systems appeared to make use of it, which may explain the absence of an incremental effect. We also find few additional effects from the SMS reminders.

Conventional approaches to agricultural extension, such as training and visit or farmer field schools, have met with mixed success (Bindlish and Evenson, 1997; Feder, 2006; Waddington et al., 2014). Information and communication technologies (ICTs) have been advanced as a promising way to overcome many of the problems associated with traditional agricultural advisory services, such as low cost-effectiveness and limited scalability (Aker, 2011). An emerging literature explores the application of different ICTs to disseminate agricultural extension information to smallholders. For instance, various studies investigate the potential for audiovisual messages as a medium to transfer agricultural extension information (eg. Gandhi et al., 2009; Maredia et al., 2017; Van Campenhout et al., 2017). Cole and Fernando (2016) evaluate the impact of a toll-free hot-line among cotton farmers in Gujarat, India. Casaburi et al. (2014) test the effectiveness of short message services (SMS) messages with agricultural advice among sugarcane farmers in Kenya, and Larochelle et al. (2019) consider the use of SMS messages to promote integrated pest management among potato farmers in Ecuador.

This article investigates the effectiveness of an ICT-mediated extension approach designed to provide information about improved maize cultivation practices to smallholder farmers in Uganda. The approach consisting of three complementary information technologies, tested in an incremental design. First, we look at the effectiveness of short audiovisual messages that provide detailed information on how to improve maize cultivation, that were shown to farmers on tablet computers. The strength of video is that it can combine audio and visual information in an attractive way that is recognizable to the potentially illiterate farmer. Second, we add an IVR service with the same information. In an IVR system, a farmer calls a phone number and navigates through a menu to select a topic. The farmer then gets to listen to a pre-recorded message with information on the selected topic. The decision to make the same information available in the form of an on-demand service is motivated by the fact that farmers may easily forgot some of the details of the video. Third, we add SMS messages that remind farmers at particular points in time during the maize growing season about key farming practices shown in the video and available on demand through the IVR system, as often information alone is insufficient to change behaviour. Timely reminders have been found very effective in overcoming inertia, procrastination, competing obligations, or simple forgetfulness of human beings (Sunstein, 2014), and repetition can make information more salient (Duflo, Keniston, and Suri, 2014). The outcomes used to assess the effectiveness of this approach and its components include increases in knowledge about improved maize cultivation, changes in the use of improved inputs and recommended agronomic practices, and production.

We draw on a field experiment involving approximately 4,000 farm households sampled from the population of households cultivating maize across five districts of eastern Uganda. We find that providing information to farmers through short videos significantly increased their knowledge about modern agronomic inputs and recommended agronomic practices. In addition, farmers who were shown the video were also more likely to adopt a range of inputs and practices that were promoted in the videos. We also find maize yields are 10 percent higher than in control households. We find that the IVR generated no additional impact on knowledge, nor did it have a strong influence on the use of modern inputs or management practices in farming. We only find a positive effect of IVR on the use of hybrid seed. However, less than 10 percent of farmers that were invited to use the IVR actually called in, raising serious concerns about statistical power. In the context of our nested design, we also find no additional effects of the SMS messages.

We contribute to the literature on how ICTs can increase the adoption of modern inputs and improved crop management practices among smallholder farmers—a topic that has received considerable attention in recent years (Nakasone and Torero, 2016; Aker, 2011). Several studies, many of which are still ongoing, have hinted at positive impacts of ICTs applied to extension services. Notable examples include Cole and Fernando (2016), who found that the introduction of a toll-free hot-line, through which farmers can ask questions to agricultural experts, significantly increased cumin and cotton yields among farmers in

Gujarat, India. Casaburi et al. (2014) found that in Kenya, sending SMS messages with agricultural advice to smallholder sugarcane farmers increased yields by 11.5% relative to a control group with no messages (but only in the first season). Fabregas et al. (2019), report positive results from six RCTs in Kenya and Rwanda that used SMS messages to increase the use of agricultural lime to reduce soil acidity and increase yields. Fu and Akter (2016) found that a multi-media mobile phone-based product linked to expert advisory services increased farmers' awareness and knowledge about specific solutions to their production constraints in Madhya Pradesh, India. Maredia et al. (2017), on the other hand, found that while mobile phone-based animated videos shown to farmers in Burkina Faso induced learning and understanding, it was no more effective in encouraging adoption than conventional approaches to information provision. In Uganda—the site of our study—Grameen Foundation had some success using smartphones to provide agriculture-related information to farmers through ICT-empowered community knowledge workers (Van Campenhout, 2017).

The remainder of the article is organized as follows. In the next section, we briefly provide some context to the study. We then present the experimental design and the models that will be used to assess impact. Next, the intervention and its components are described. We then turn to the results, assessing the impact on knowledge, adoption, and production. This is followed by a section with additional analysis and robustness tests, that looks at take-up of the different components, experimenter demand effects, heterogeneity in treatment effects, and attrition. We then reflect on cost-effectiveness of the intervention and draw conclusions in a final section.

1 Context

The study was conducted among smallholder maize farmers in Uganda. Maize is widely consumed throughout much of Uganda, yet its value-to-weight ratio is sufficiently high to also make it an important traded commodity. Therefore, efforts to increase maize productivity at the farm-household level are an important dimension of Uganda's strategy to increase food security and reduce poverty through both consumption and income channels. Maize yields in Uganda are low when compared to neighboring countries and global averages: While research station trials conducted in Uganda report potential yields of about 1.6 metric tons per acre (using only improved varieties without fertilizer application), data from the Uganda National Household Survey (UNHS) 2005/06 indicate that average maize yields are much lower at about 618 kg per acre for the main growing season.

The use of modern inputs is notoriously low in Uganda (probably because of the inherently fertile land and the abundance of rain). Bold et al. (2017) report that only 9 percent of maize cultivating households use inorganic fertilizer. In Tanzania, this is almost 20 percent, while in Malawi, heavy subsidies increase this rate to 80 percent. Furthermore, they report that about 27 percent of maize farmers reports using improved seed. In both Tanzania and Malawi, one in two farmers report using improved seed. Experts also told us that low yields are due to farmers not adhering to recommended practices.

Uganda has been struggling to set up a functioning extension service. In 2000, the National Agricultural Advisory Services (NAADS), an ambitious public private partnership was set up with support from various donors. After what seemed to be a successful start, NAADS became a victim of political capture and governance problems, culminating in its demise and replacement by Operation Wealth Creation (Benin et al., 2011; Joughin and KjÃŠr, 2010; Rwamigisa et al., 2018). Operation Wealth Creation is managed by the armed forces, and primarily focused on the distribution of inputs. Today, access to information through public extension services is limited. The last available data, obtained from the Uganda National Panel Survey (wave 2013/2014) suggests 20 percent of household received extension in the past 12 months. Recently, private initiatives and international social enterprises have started to fill the void. For example, Viamo's 3-2-1 service provides agricultural information through IVR. The Market-led, User-owned ICT4Ag-enabled Information Service (MUIIS) project uses ICT to facilitate farmer-to-farmer extension. Through the m-Omulimisa platform, farmers can sent SMS messages with questions to agricultural extension officers.

In eastern Uganda, there are two maize cropping seasons. For our study, we concentrated on the second maize-growing season of the year 2017, which ran from approximately August 2017 to January 2018 and is characterized by a shorter period of rainfall than the first maize-growing season. During this second season, the complete cycle from planting to harvest requires 3 to 3.5 months, and farmers tend to cultivate early-maturing but lower-yielding maize varieties as a result. Fields are prepared in August, planted in September, an harvested beginning in mid to late December and, at higher elevations, through mid January.

2 Experimental Design and Estimation of Treatment Effects

We evaluate the effectiveness of ICT-mediated agricultural extension using a field experiment (de Janvry, Sadoulet, and Suri, 2017)[1]. The experiment has four treatment arms, and the IVR and SMS treatments are incremental in design. The experimental units are the households, who were randomly assigned to one of these four arms. A total of 3,703 households were shown a video, while 256 households (our control group) were shown a placebo video. From the 3,703 households that were shown a video, 2,414 also received an IVR starter kit: a flyer containing a toll-free phone number and instructions on how to use it. From the 2,414 households that were shown a video and received the IVR encouragement, 1,113 households were also allocated to the SMS treatment[2].

Maize is especially important in eastern Uganda. We sampled from five districts in eastern Uganda known for their maize production: Bugiri, Mayuge, Iganga, Namayingo, and Namutumba. From these districts, we removed town councils and also two sub-counties that consisted of islands in lake Victoria. We used two-stage cluster sampling to obtain a representative sample of this population. In particular, from the five districts, we first selected 50 parishes randomly and in proportion to the number of villages within each parish.

Within each village in the selected parishes, we then listed all households, from which we randomly selected 10 households to participate in the study. In each village, one of the 10 households was randomly allocated to the control group (which got to see a placebo video). The remaining 9 households were all shown a video. We then added the IVR treatment randomly to 2/3 of the households that were allocated to the video intervention and further randomly allocated 1/2 of these households to the SMS treatment[3].

To evaluate the effectiveness of these different ICT channels, we start by comparing average household-level outcomes among households that were shown a video to average outcomes of households from the control group. This gives us the average treatment effect for the video intervention. To obtain the additional effect of the IVR treatment, we compare average outcomes of households that were shown a video and received the IVR intervention to households that were shown only a video. Finally, the additional effect of the SMS campaign is estimated by comparing outcomes of household that were shown a video, received IVR information and also received the eight SMS reminders to outcomes of households that are shown a video and received the information about the IVR system, but did not get the SMS reminders. In practice, this is done using a simple ordinary least squares (OLS) regression of the form:

$$y_i = \alpha + \beta_1 video_i + \beta_2 .IVR_i + \beta_3 .SMS_i + \varepsilon_i \tag{1}$$

with y_i the outcome used to assess impact as reported by household i; $video_i$ a dummy variable that is one if household i was shown a video and zero otherwise; IVR_i a dummy variable that is one if household i was given an IVR starter kit and zero otherwise; SMS_i a dummy variable that is one if household i was sent SMS messages and zero otherwise. In this regression, α is then the average outcome in the control group, β_1 provides an estimate of the effect of having been shown a video, β_2 provides an estimate of the incremental effect of also having been allocated to the IVR intervention and β_3 provides an estimate of the incremental effect of also having been allocated to the SMS intervention.

While we did not conduct a dedicated baseline survey, we did collect some information prior to the experiment's roll-out to investigate balance. The choice of variables was based on those variables that other researchers in similar studies used in their orthogonality tests. In particular, we looked at balance tables in studies that investigate the adoption of yield-improving technologies and practices using randomized controlled trials (RCTs), including Duflo, Kremer, and Robinson (2011), Karlan et al. (2014), Ashraf, Gine, and Karlan (2009) and Bulte et al. (2014). We collected household characteristics such as household size, age, and, education level of household head. We then asked more specific questions related to maize farming, such as acreage and quantities produced in the last season. Furthermore, we asked if the household received agricultural extension services, whether it used improved maize varieties, and whether it applied inorganic fertilizer to maize. We also collected data on housing conditions (number of bedrooms) and distance to the nearest agro-input shop. As mobile phone ownership is relevant to the IVR and SMS interventions, we also report balance on household access to and ownership of a mobile phone.

In Table 1, we provide descriptive statistics and balance tests for the comparisons between the three information delivery packages. Averages for the control group are reported in the first column. We observe that few households that were included in our study had access to agricultural extension in the previous year (about 11 percent). We also observe that only about 17 percent of households reported to have used any fertilizer in the previous season, and about 34 percent reported to have used improved seed bought from a shop or agro-input dealer during the last cropping season. This suggests ample scope to increase intensification investments through extension. We also find that farmers produced on average only 268 kg of maize per acre in the first cropping season of 2017. This is substantially lower than the average yield of 618 kg per acre we find in data from the 2005/06 Uganda National Household Survey. The low yields reflect the devastating impact of the fall armyworm outbreak and adverse weather conditions that plagued East Africa in 2017 (Stokstad, 2017).

Balance is tested by judging the significance of coefficient estimates in a regression (equa-

Table 1: Balance at baseline for ICT channel used to deliver information

	Mean	Video	+IVR	+SMS	N
Maize yield (kg/ac)	267.93	17.41	7.57	-9.15	3,959
	(230.20)	(18.97)	(11.30)	(11.93)	
Age of HH head (years)	40.50	-1.05	0.87*	-0.73	3,910
	(14.33)	(0.88)	(0.52)	(0.55)	
HH head finshed primary school	0.37	-0.01	0.02	0.00	3,959
	(0.48)	(0.03)	(0.02)	(0.02)	
HH size	7.72	-0.30	0.42***	-0.21	3,959
	(3.17)	(0.22)	(0.13)	(0.14)	
Number of bedrooms	2.32	-0.12	0.10**	-0.09*	3,959
	(1.21)	(0.08)	(0.05)	(0.05)	
Access to extension last year	0.11	0.00	0.00	0.01	3,959
	(0.31)	(0.02)	(0.01)	(0.01)	
Has used fertilizer last season	0.17	0.04	0.01	-0.01	3,959
	(0.37)	(0.03)	(0.02)	(0.02)	
Has used improved seed last season	0.34	0.04	0.01	-0.01	3,959
	(0.47)	(0.03)	(0.02)	(0.02)	
Distance nearest agro input shop (km)	5.18	0.17	0.13	0.34	3,959
	(4.89)	(0.36)	(0.22)	(0.23)	
HH owns mobile phone	0.76	0.01	0.01	0.01	3,959
	(0.43)	(0.03)	(0.02)	(0.02)	
HH has access to a mobile phone	0.84	-0.01	0.02	-0.01	3,959
	(0.36)	(0.02)	(0.01)	(0.02)	
F-test		0.820	1.186	1.143	
P-value		0.621	0.291	0.323	

Note: First column reports control group means (and standard deviations below); Column 2 reports differences between placebo (control) and video treatment (and standard error below), column 3 between video only and video+ivr, column 4 between video+ivr and video+ivr+SMS; the last column is sample size; ***, ** and * denote that the difference is signficantly different from zero at the 1, 5 and 10 percent level, respectively.

tion 1), and with a joint significance test (F-test). The second column in Table 1, denoted "Video", compares baseline characteristics between households that were shown the placebo video (control group) and households that were shown an intervention video (β_1 in equation 1). For example, we see that yields prior to the intervention were about 17 kg per acre higher in the group that was shown the intervention video than in the group that was shown the placebo video. However, this difference is not significantly different from zero. In fact, for the placebo video versus intervention video comparison, none of the differences in baseline characteristics is significant at the 10 percent significance level, and the F-statistic can not be rejected. In the third column, differences in baseline characteristics between households that received the intervention video and households that received the IVR starter kit on top of the video are shown (denoted "+IVR"; corresponding to β_2 in equation 1). Here, we see that, at baseline, households in the latter group were significantly larger than households that only saw the video. They also had significantly more bedrooms and the household head was slightly older. However, we can again not reject the null that jointly, baseline characteristics were unrelated to the treatment group for this comparison. For the final comparison (comparing farmers that received video and IVR to those that additionally received SMS messages; reported in column four and denoted "+SMS" and corresponding to β_3 in equation 1), we find that treatment household had slightly fewer bedrooms, but the figure is only significant at the 10 percent level and the joint test does not reject overall balance.

We find that about 84 percent of households had access to a mobile phone prior to the intervention. This is encouraging, as the usefulness of IVR depends on access to a mobile phone. Further, we find that there was no difference in this percentage between the various treatment groups. The incidence of mobile phone ownership was also high, with about three quarters of households reporting they own a mobile phone. Again, this is important as the potential effect of the SMS intervention depends on being able to receive the messages.

3 ICT intervention

The comprehensive ICT-mediated extension approach consisted of three ICT interventions: a short video, an encouragement to use an IVR system, and series of 8 SMS messages. The videos were shown on 10-inch Android tablet computers and screened by a trained field enumerator during a one-to-one meeting with either an individual farmer or the male and female co-head[4]. The control group received a placebo treatment, which was a music video of traditional dancing that contained no information related to farming or maize (Bernard et al., 2015). Videos (treatment or placebo) were screened twice to the households in the sample, once before the time for planting maize (August 2017) and once around planting time (September 2017).

The information contained in the treatment groups' video is expected to positively influence maize yields by encouraging the adoption of several improved technologies and practices. The topics included in the video script were obtained from qualitative interviews with key informants that were conducted in May 2017. The key informants included maize farmers, traders, maize breeders, extension workers, district agricultural officers, and other government staff and experts.

A significant portion of the videos focuses on providing technical information on seed choice, soil nutrient management (including the promotion of both organic and inorganic fertilizer application), weeding (with particular attention on fighting striga, a parasitic weed that feeds off the roots of the maize plant), timely planting, and plant spacing, which were ranked among by the experts as the top challenges farmers face. We made sure to include information that is likely to be unknown to the farmer, as information is likely to be most valuable when individuals learn about a new technology or institutional innovation. However, other studies also provide evidence of behavioral change occurring through the compounding or re-emphasis of common knowledge that, through repetition, becomes more salient to the individual (Duflo, Keniston, and Suri, 2014). Therefore, the videos also contain information that farmers are assumed to know but do not seem to act upon.

Not all constraints to maize productivity improvement are information deficiencies directly related to the use of inputs, technologies, and crop management practices. Often, missing information problems manifest indirectly, as uncertainty about the distribution of the farm-household's profit function. This includes uncertainty about the correlations between expected and actual returns, the inter-temporality of income streams, estimates of fixed and variable costs, hidden transactions costs, probabilities of adverse events, and a range of other variables that farmers may simply be unable to conceptualize or measure. Thus, a significant portion of the videos also focuses on evaluating the costs and benefits of the different technologies and practices being promoted. In addition, the videos encourage long-term thinking, advising farmers to (a) start small and grow their farm enterprise over time, and (b) combine technologies and practices together rather than investing all of their money and effort into one single input, practice, or technology.

We also pay attention to how the information is packaged. For instance, prior studies have found that farmers find communicators who face agricultural conditions and constraints most comparable to their own to be the more persuasive than other communicators (BenYishay and Mobarak, 2018). Several studies point out the importance of role models on aspirations and future-oriented behavior (Bernard et al., 2015). A growing strand of the literature investigates how non-cognitive farmer characteristics such as aspirations, locus of control and self-esteem can lead to behavioral change such as technology adoption (Abay, Blalock, and Berhane, 2017). Therefore, in our video, the message is conveyed by individuals who are readily recognized as "peer farmers" and who provide information that is framed as a success story.

The two other treatments were incrementally added to the video treatment. For these two treatments, the IVR system and the SMS reminders, we collaborated with Viamo, a social enterprise that aims to connect individuals and organizations using digital technology to make better decisions. We set up an IVR system that provided the same information as was recommended in the video. Farm households that were allocated the IVR treatment were encouraged to call a toll-free number which explained the IVR system in their own language. The caller is then invited to select the number corresponding to the topic on which he or she wants more information (e.g., “Press 1 for seed selection, 2 for spacing and seed rate, 3 for soil nutrient management, 4 for advice on weeding”). Depending on what number was selected, the IVR then played an audio message of a conversation between two farmers, where one farmer is explaining the recommended practice to the other farmer.

For the SMS campaign, we recorded telephone numbers for mobile phones owned by the household head at the time of the experiment's roll-out. Households that were allocated to the SMS treatment were sent eight SMS messages over the course of the two months following the first screening of the video. The messages all followed a similar structure: farmers were first reminded about an important technology or practice that was relevant at the particular time that the message was sent, followed by a reminder about the existence of the IVR service. The reminders were related to technologies and practices that were also promoted in the video and IVR. For example, the first message, that was sent out around planting time, read “You will get much more maize if you use hybrid seed instead of recycled seed. Call the maize hot-line on 0200522420 free for more advice!”. About one month into the growing season, the following message was sent: “When your maize is knee high, apply 1 water bottle cap of urea around each plant. Call the maize hot-line on 0200522420 free for more advice!”. All content was produced in the local language (Busoga).

4 Results

We now turn to the results. We first estimate intent-to-treat (ITT) effects for the (incremental) impact of the three information technologies on a range of outcomes related to knowledge, adoption of recommended practices and use of modern inputs, and production.

4.1 Impact on knowledge

We first estimate the incremental impact of the three different ICT channels on knowledge outcomes. Knowledge outcomes were measured with a short quiz (Feder, Murgai, and Quizon, 2004a,b; Masset and Haddad, 2015) consisting of four multiple-choice questions that were asked during the endline survey to each of the two spouses in the farm household separately. For each question, three possible answers were read out to the respondent, who was then asked to indicate which answer he or she thought was correct (which may differ from what he or she recalled from the video). The respondent was also allowed to indicate if he or she did not know the correct answer. The household was considered knowledgeable on a particular topic if at least one of the spouses could indicate the correct answer.

The first question was related to planting. In our video, we recommended a spacing of 75cm x 30cm with one seed per hill, and this was the correct option. Other possible answers included a spacing of 75cm x 60cm with two seeds per hill, which is standard for many farmers and recommended by many agricultural extension agents, and an intermediate alternative of 75cm x 30cm with two seeds per hill. Because our video recommended a technique that deviates from what is assumed to be standard spacing, we assumed that the recommended practice is new to most of the farmers. This question thus tests a traditional theory of change, where extension generates knowledge, which leads to increased adoption and subsequently boosts yields.

The second question is less related to technical knowledge, but more to viewing farming as a business. In the video, we paid ample attention to promoting an approach where farmers start small and grow over time by reinvesting, and we emphasized the benefits of combining inputs rather than investing only in e.g., improved seed. We wanted to see if farmers internalize this advice and ask what a successful farmer would do if he or she only has 40,000 shillings. The correct answer was to use this amount to purchase improved seed and fertilizer and start intensified farming on a small area. Alternative options were to: "use all the money to buy hybrid seeds, because without good seeds, yields will be low"; and "use all the money to buy fertilizer, because with poor soils, yields will be low". This question suggests impact works more through aspirational channels, testing if farmers understood the broader message given in the video that successful farmers generally see maize farming more as a business which requires foresight and risk taking.

For the third question, we asked if farmers knew when weeding is most important. The video showed that weeding is most important during the first four weeks after planting, as maize is a poor competitor for light and nutrients. We assumed that most farmers would know the correct answer to this question given that weeding is part of well-established management practices in the study area. Alternative answers were: "when the maize is knee high" and "when the maize is at tasseling stage". The relevant theory of change here is that ICT interventions may be used to make a known technology more salient.

Finally, we asked if farmers knew when spraying against fall armyworm is most effective. No information was given about fighting fall armyworm in the intervention, so unless our intervention encouraged farmers to search for additional information, we do not expect any impact. For this question, the correct option was: "During the evening, as fall armyworm eats during night," while the other options were: "Early in the morning when it is still cool" and "At noon because sunlight increases chemical performance."

To guard against over-rejection of the null hypothesis due to multiple inference, outcomes of the knowledge questions were combined into an index, constructed as the weighted mean of the individual standardized outcomes, using as weights the inverse of the co-variance matrix of the transformed outcomes (Anderson, 2008). However, we also see value in examining the impact on the questions individually, as they attempt to measure different aspects of the information intervention. To control the family-wise error rate (FWER) when examining results for each question individually, we use re-randomization to construct the joint null distribution for the family of outcomes we are testing. From this family-wise sharp null, we can obtain the corresponding FWER-consistent significance thresholds by determining which cut-offs yield e.g., 10 percent-, 5 percent-, and 1 percent significant hypothesis tests across all tests and simulations.

Table 2 shows results for the three incremental levels of ICT-mediated information delivery using different information technologies[5]. The first column reports mean scores in the control group (with standard deviations reported below in parentheses). For the four individual questions, this is simply the proportion of households in the control group that answered correctly on the particular question. For instance, we find that in almost 16 percent of the households in the control group, at least one of the spouses indicated the correct option among the response alternatives to the question on optimal maize seed spacing. This relatively low rate of correct responses is due to the fact that this is a fairly new recommendation that deviates from what farmers have been taught in the past and have been doing for decades. We find that in about 91 percent of control households, at least one spouse knew inputs were best combined and in more than 95 percent of households it was known that weeding is most important during the first 4 weeks. In about one third of the households, at least one spouse knew how to fight fall armyworm. For the knowledge index, the mean is harder to interpret, as it is the result of a weighted mean after standardization of the individual components of the index.

In the second column, we report the impact of having been shown the video (with standard errors of the estimated coefficient reported below in parentheses). We find that having been shown the video increases the likelihood that at least one individual knows the recommended spacing by 13.2 percentage points and this difference is significantly different from zero at the 1 percent FWER-adjusted significance level (randomization inference-based p-value are shown in the third column; asterisks denote significance as compared to FWER-adjusted thresholds). We also find that the video increased the likelihood that at least one spouse indicates that inputs are best combined for optimal results by 4.5 percentage points. This difference is statistically significant at the 5 percent FWER-adjusted significance level. For the question on weeding, the intervention does not seem to have had a significant effect. However, this result should be interpreted with care due limited variation in the outcome.[6]

Table 2: Impact of ICT treatments on knowledge outcomes

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Knows optimal spacing (yes=1)	0.155	0.132***	0.000	-0.020	0.227	0.010	0.571	3,629
	(0.363)	(0.030)		(0.018)		(0.019)		
Knows inputs best combined (yes=1)	0.908	0.045**	0.011	-0.016	0.114	0.009	0.416	3,629
	(0.290)	(0.018)		(0.011)		(0.011)		
Knows optimal time for weeding (yes=1)	0.954	-0.017	0.323	0.009	0.357	-0.002	0.811	3,629
	(0.210)	(0.017)		(0.010)		(0.011)		
Knows how to fight armyworm (yes=1)	0.336	-0.018	0.590	-0.017	0.503	0.019	0.310	3,629
	(0.473)	(0.031)		(0.019)		(0.020)		
Knowledge index	-0.075	0.089***	0.002	-0.021	0.335	0.056	0.561	3,629
	(0.565)	(0.041)		(0.025)		(0.026)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

Finally, on the fall armyworm question, we find that households that were shown the video are no more likely than control households to know when one should spray to control the pest. This suggests that the videos did not encourage farmers to actively search information on important challenges that were not explicitly covered in the video. Overall, and as confirmed by the knowledge index, we conclude that the agricultural extension videos increased knowledge at the household level, and that this increase seems especially poignant for novel information provided in the videos.

The fourth column (+IVR) shows the incremental effect of IVR (with standard errors of the estimated coefficient reported below in parentheses, and corresponding randomization inference-based p-value in the fifth column). We see that being provided with an IVR encouragement does not additionally affect knowledge about the new recommended spacing. Similarly, there is no additional effect on knowledge related to the optimal time for weeding and also no additional effect on knowledge about the best way to fight fall armyworm. The fact that there is no supplementary effect of the IVR encouragement on knowledge is confirmed by the non-significant difference in the knowledge index. The sixth column (+SMS) reports the additional effect of the SMS reminders on the various questions and the index (with randomization inference-based p-value reported in the seventh column). Similar to the impact of IVR, we do not find an additional effect of the SMS campaign on any of the questions. We also do not find an effect of the SMS campaign as judged by the knowledge index. The fact that the IVR and SMS components have no additional knowledge effects is perhaps not surprising, as they did not provide new information.

4.2 Adoption effects

Next, we consider changes in household-level adoption of recommended farming practices as a result of the intervention. During the endline survey, we collected detailed information on practices employed on the household's maize plots. Results of mean adoption rates in the control group for different practices are reported in the first column of Table 3. For instance, in the video, we recommend to start planting maize immediately after the start of the rains. We find that 37 percent of households in the control group reported that they started planting within one day after the start of the rains on at least on plot—a relatively high rate of adoption for this practice that indicates the extent to which it is likely known among farmers. We also find that only 2.6 percent of households in the control group used the recommended way of plant spacing of 75cm x 30cm with a reduced seed rate of 1 seed per hill. This low rate in the control group is not surprising given that this was a new recommendation. Almost 69 percent of control households report removing striga before it flowered to reduce damage early on and prevent the weed from spreading. Finally, we find that about 43 percent of control households reported first weeding after 18-20 days as recommended in the video.

The second column in Table 3 again reports the difference in the adoption of practices between households that were shown the intervention video and households that were give the placebo treatment (with standard error of the estimate in parenthesis below and corresponding randomization inference-based p-values in column 3). We find that for the first recommended practice, timely planting, there is no impact from the video treatment. However, the likelihood that households adopt the recommended 75cm x 30cm spacing with a reduced seed rate increases significantly after having been shown the video: while only 2.6 percent of households in the control group report adopting this practice on at least one plot, this figure increases to 8.8 percent among households that were shown a video (and this difference is significant at the 1 percent FWER-corrected significance level). Similarly, we find that the proportion of households that removed striga early on increased from 68.9 percent to 74.6 percent as a result of being shown a video (randomization inference-based p-value of 0.030, significant at the 10 percent FWER-corrected significance level). Finally, while the proportion of households that reported having started weeding after 18-20 days is higher among households that were shown the video, the difference is not significantly different from zero. Estimation results for the index that summarizes the different practices

Table 3: Impact of ICT treatments on adoption of recommended practices

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Planted immediately after start of rains (yes=1)	0.366	-0.001	0.966	0.008	0.673	-0.002	0.919	3,509
	(0.483)	(0.033)		(0.020)		(0.021)		
Used spacing of 75cm x 30cm with a reduced seed rate (yes=1)	0.026	0.062***	0.001	-0.003	0.776	0.013	0.236	3,572
	(0.158)	(0.019)		(0.011)		(0.012)		
Removed striga early on (yes=1)	0.689	0.057*	0.030	-0.005	0.819	0.020	0.240	3,572
	(0.464)	(0.030)		(0.018)		(0.019)		
First weeding after 18-20 days (yes=1)	0.430	0.015	0.682	0.012	0.560	-0.006	0.789	3,572
	(0.496)	(0.034)		(0.021)		(0.022)		
Recommended practices index	-0.083	0.077***	0.006	0.009	0.670	0.039	0.378	3,509
	(0.473)	(0.036)		(0.022)		(0.023)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

confirms that overall, we can conclude that the videos significantly increased the adoption of recommended practices.

The fourth and fifth column of Table 3 report results for the additional effect of the IVR encouragement, with estimates reported in column 4 and the corresponding randomization inference-based p-values in column 5. We do not find any significant additional effect of the IVR treatment on any of the recommended practices. The sixth and seventh column report results for the additional effect of the SMS campaign, with estimates reported in column 6 and the corresponding randomization inference-based p-values in column 7. While we do find that the proportion of households that reports to be removing striga before flowering is 20 percentage points higher in the treatment group, and while we also find a small positive effect on seed spacing and seed rate, the differences are not significant. The fact that the both the IVR encouragement and the SMS campaign has no additional impact on adoption of practices is confirmed by the indices.

Next, we examine results related to the use of modern inputs. During the endline survey, we collected detailed information on input use on the household's maize plots, specifically on the use of fertilizer and improved seed. Results are reported in Table 4. In the top panel of the table, we look at the three types of fertilizer that were recommended in the video separately, and again use an index to assess changes in overall fertilizer use. The first column in Table 4 reports mean adoption rates in the control group. We find that 26 percent of control households report that they used DAP or NPK on at least one of their maize plots, while the use of urea is less widespread with only 5.1 percent of control households reporting urea use on at least one plot. Among control households, 16.2 percent reported using organic fertilizer on at least one plot.

The impact of showing videos on fertilizer use is reported in column 2 and 3 of Table 4. We see that the video treatment increased the use of Urea by 5 percentage points (with a randomization inference-based p-value of 0.011, and significance at the 5 percent level after controlling FWER). We also find that the use of organic fertilizer increased by about 7.3

Table 4: Impact of ICT treatments on fertilizer and improved seed use

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
				fertilizer use				
Used DAP/NPK on at least one plot? (yes=1)	0.260	-0.043	0.119	0.022	0.159	-0.007	0.699	3,572
	(0.439)	(0.029)		(0.017)		(0.018)		
Used urea on at least one plot? (yes=1)	0.051	0.050**	0.011	0.013	0.277	-0.023	0.071	3,572
	(0.221)	(0.020)		(0.012)		(0.013)		
Used organic fertilizer on at least one plot? (yes=1)	0.162	0.073**	0.007	-0.038*	0.024	0.030	0.070	3,572
	(0.369)	(0.028)		(0.017)		(0.018)		
Fertilizer index	-0.056	0.065**	0.038	-0.003	0.887	0.016	0.953	3,572
	(0.548)	(0.040)		(0.024)		(0.025)		
				improved seed use				
Used hybrid maize seed on at least one plot? (yes=1)	0.294	0.003	0.925	0.041**	0.028	-0.049*	0.009	3,572
	(0.456)	(0.031)		(0.019)		(0.020)		
Used Open Polinated Varieties on at least one plot? (yes=1)	0.298	-0.027	0.410	0.012	0.493	0.025	0.393	3,572
	(0.458)	(0.031)		(0.019)		(0.020)		
Seed index	0.032	-0.068	0.551	0.059**	0.025	0.016	0.429	3,572
	(0.693)	(0.046)		(0.028)		(0.029)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

percentage points as a result of the video treatment. Summarizing the three types of fertilizer in a index results in a positive difference between treatment and control, with the difference significant at the 5 percent level.

The incremental impact of the IVR encouragement is reported in columns 4 and 5 of Table 4. While the difference between treatment and control is positive for both types of inorganic fertilizer, the effects are not significant. However, we do find that the IVR encouragement reduced the proportion of households that reported using organic fertilizer by 3.8 percentage points. The opposing effects result in an insignificant index. The additive effect of the SMS campaign is reported in columns 6 and 7 of Table 4. We do not find an effect of the SMS campaign on fertilizer use.

In the lower panel of Table 4, we report results for the use of improved seed. We differentiate between maize hybrids and open-pollinated maize varieties. Use rates are about the same for both types. We do not find that the video treatment changes these percentages (columns 2 and 3). However, we do find an effect from the IVR encouragement: the percentage of households that reported to have used hybrid seed on a least one plot was 4.1 percentage points higher in the treatment group. Apparently, providing farmers with a tool that allows them to actively seek out information about a new input or technology increases the likelihood that they also adopt hybrid maize seed[7]. The impact of the IVR treatment on improved seed use is confirmed by the seed index. The SMS campaign appears to counteract the effect of the IVR on hybrid seed use.

4.3 Production effects

Finally, we now turn to the intervention's effects on production-related outcomes. We first examine household-level maize production. During the endline survey, we asked both spouses separately to estimate how much maize was harvested from each maize plot. These quantities were then summed over the different maize plots assessed by each spouse and the average between the two spouses was taken as the final estimate of household-level maize production.

The first column in Table 5 shows mean values for the production indicators for the control group. On average, control households produce (log(kg)) 5.825 or about 440 kg of maize. This was cultivated on (log(acre)) 0.019 or about 1.19 acres on average. It also shows that for the average household in the control, maize yields (log(kg/acre)) equal 5.846 or about 430 kg/acre. This is much higher than yields recorded at baseline (290 kg/acre) for the previous season, possibly because rainfall patterns were better during our intervention and farmers may have given greater attention to combating fall armyworm. Still, compared to figures recorded in FAOSTAT (1,000 kg/acre) or figures from household survey data (typically around 600 kg/acre), yields were below what might be considered "normal" in Uganda. This is also confirmed by the fact that in less than 40 percent of households at least one spouse reported that yields were better than a typical year on at least one plot. We also look at labor use. The average household spent about 72 person-days on maize farming, which includes labor that was hired in. This translates in a labor productivity of 6.73 kg of maize per hour worked.

In the second column of Table 5 we report the impact of the video treatment (with corresponding randomization inference-based p-values in column 3) for the various production related outcomes. We see that there is no impact on (log) maize production. However, we do see that households in the video treatment produced this same amount of maize on an area that is about 10.5 percent smaller than the area used for maize production by control households. As a result, we also find that among households in the video treatment, yields are about 10.5 percent higher than among the control group, and this difference is significant at 10 percent after controlling FWER. The fact that the video intervention has a clear effect on production-related outcomes is also reflected in the significant different in the production index (aggregating amount produced, area cultivated, labour used and a subjective assessment of maize yield) between treatment and control. That said, we do not find that households in the video treatment were more inclined to feel that yields are better than normal than control households[8].

Table 5: Impact of ICT treatments on production outcomes

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Maize production (log(kg))	5.825	-0.017	0.747	0.045	0.316	0.042	0.351	3,347
	(0.754)	(0.059)		(0.034)		(0.036)		
Maize area (log(acre))	0.019	-0.100*	0.020	-0.010	0.683	0.023	0.390	3,339
	(0.579)	(0.045)		(0.026)		(0.028)		
Maize yield (log(kg/acre))	5.846	0.100*	0.025	0.039	0.292	-0.002	0.935	3,301
	(0.658)	(0.049)		(0.028)		(0.030)		
Yield better than normal (yes=1)	0.387	0.023	0.496	0.001	0.971	0.035	0.133	3,572
	(0.488)	(0.034)		(0.020)		(0.021)		
Labour (log(mandays))	4.134	-0.010	0.786	-0.010	0.706	0.036	0.122	3,381
	(0.580)	(0.042)		(0.024)		(0.026)		
Labour productivity (log(kg/mandays))	1.650	0.024	0.649	0.073	0.062	-0.009	0.750	3,346
	(0.719)	(0.056)		(0.033)		(0.035)		
Production index	-0.050	0.043**	0.024	0.007	0.607	0.026	0.565	3,297
	(0.364)	(0.025)		(0.015)		(0.016)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

Results are again consistent with the content provided in the video. In particular, the video advised that farmers experiment on a small part of their field with modern inputs, following recommended practices, and advised against using improved seed on their entire field if this does not leave sufficient money for complementary inputs such as fertilizer. Further, the video advised farmers to cultivate a more commercial mindset, paying ample attention to the idea of starting small and growing over time through re-investing. Columns 4 and 5 report the additive effect of the IVR treatment on production-related outcomes. As with previous outcomes, there seems to be little impact from this treatment. Similarly, we do not find additional effects on production related outcomes of the SMS campaign.

5 Additional analysis and robustness tests

While we find significant effects from the video intervention, we find limited additional effects from the IVR and SMS treatments. In this section, we explore potential reasons for this and provide some further analysis to explore the robustness of our findings.

5.1 Demand for IVR and Local Average Treatment Effects

In an encouragement design such as the IVR treatment, households self-select into the treatment. Judged by the call log of the IVR system, we find that only a small number of households that were encouraged to use the IVR system also actually called in (8.9 percent or 214 households). It may be instructive to look at differences in baseline characteristics between households that decide to make use of the IVR system and those that do not. Appendix Table A.5 therefore shows the results of an ordinary least squares (OLS) regression of an indicator that takes the value of one if the IVR system log showed that a household called in at least once using the phone number that was recorded during baseline data collection and zero otherwise on various baseline variables (and the SMS treatment allocation). Results show that none of the baseline characteristics predict demand for the IVR service, except for access to a mobile phone. We also find the SMS messages seemed to have increased the likelihood that farmers called the IVR hotline as intended.

As demand for the IVR service is endogenous, we can not simply compare outcomes of households that called into the system to those that did not. Furthermore, it may be that farmers that were provided with information on the IVR passed this on to households that were shown the video but were not allocated to the IVR treatment. Contamination of the control group may lead to a downward bias of the treatment effect as estimated in the previous section. However, with two-sided non-compliance, Local Average Treatment Effects (LATE) can be estimated, where the random allocation of the treatment is used as an instrument for the variable that measures calling into the IVR system (Imbens and Angrist, 1994).

Tables A.6 to A.9 in the Appendix provide tables that correspond to Tables 2 to 5 showing LATE estimates for IVR additional effects. In all these tables, means and standard deviations in the control group are repeated for reference in the first column. In the second column, results of a 2 stage least squares (2SLS) regression where we instrument a dummy variable that a household called the IVR with the random allocation to the IVR treatment, are reported. We report point estimates together with standard errors in brackets below; corresponding p-values are in the third column. The same structure is used in all Appendix Tables A.6 to A.9.

Results do not change much from what we found in the previous section. For knowledge related outcomes and the use or recommended practices (Appendix Tables A.6 and A.7), point estimates for the IVR impact are generally much higher in absolute value, but remain insignificant. Appendix Table A.8 confirms the previous finding that the likelihood of using organic fertilizer reduces among households that called into the IVR system. For seed use, we find results that are again similar to the previous section, with IVR increasing the likelihood of using hybrid seed. Now the seed index is not significant anymore. Finally, few effects show up as significant when production related outcomes are considered (Appendix Table

A.9).

Thus, even after accounting for non-compliance, we find that additional effects from the IVR treatment are limited, particularly when judged by outcome indices. A first reason why we fail to find significant effects that are consistent with the effects from the video for the additional treatment may be because the partial compliance greatly reduces the power of the design. Only 8.9 percent of households that were selected for the IVR treatment also actually called in[9]. This low compliance rate may reflect low demand for the service[10]. Contamination, where farmers that were allocated to the control group end up calling the IVR, may also lead to a downward bias in the estimates. However, we find that only one percent of farmers that were allocated to the control group called the IVR system.

Furthermore, in our context, we have additional reason to be suspicious of the LATE results. Our indicator of take up of the intervention is likely to be measured with significant error. In particular, our indicator of compliance is taken from the IVR system log, where recorded telephone numbers are matched to phone numbers that were recorded during baseline data collection. This indicator is likely to severely under-report true compliance, as encouraged farmers may use different phones to call the IVR[11]. Using our measure of compliance, we can not maintain that the independence assumption holds, as some of the potential outcomes are directly determined by the instrument. The problem becomes apparent when we think about LATE as the Wald estimator that scales the ITT by compliance (Angrist and Pischke, 2008). In our case, the ITT will be estimated on the basis of all 430 farmers that called in. Our measure of compliance will force all the impact of the treatment to work through the 214 households that show up in the IVR log and could be identified in the baseline, which in the case of a positive impact would lead to an overestimate of the impact of the treatment on compliers. It is well know that especially in the context of a weak first stage the bias can become extremely large (Duflo, Glennerster, and Kremer, 2007)[12]. The above may make interpretation of the LATE effects difficult. We thus recommend focusing on ITT effects.

5.2 Experimenter demand effects

A key concern with this study is the use of self-reported survey data on key outcomes, as opposed to outcomes that are measured by a third party in an objective way. Study participants may report what they feel is desired in that context (social desirability bias). In an RCT, social desirability bias becomes a real concern if it is correlated to the treatment, which is sometimes referred to as experimenter demand effects (Zizzo, 2010). While recent research suggests that experimenter demand effects may be less problematic than initially thought (eg. De Quidt, Haushofer, and Roth, 2018; Mummolo and Peterson, 2019), we provide some discussion on why we feel experimenter demand effects are unlikely to drive our results.

First, during the design of the endline questionnaire, we tried to minimize potential experimenter demand effects by careful formulation of the questions. Experimenter demand effects are more likely to be a concern for simple yes/no questions than for more open ended questions. For instance, in our endline survey, we did not ask if farmers used "plant spacing of 75cm x 30cm with a reduced seed rate of 1 seed per hill" as recommended. Rather, we asked farmers to describe the planting process, and the enumerator was then asked to select the appropriate response from a list of options that was not revealed to the farmer. For input adoption, we started from broad questions (eg. whether fertilizer was used on a particular plot) and then asked farmers to go further into detail (eg. asking about fertilizer type, timing of application, quantities and price) allowing enumerators to detect inconsistencies that may signal experimenter demand effects.

Second, in our endline survey, not all outcomes are equally likely to be affected by experimenter demand effects. For instance, experimenter demand effects are probably less likely to be an issue for the multiple choice questions used to measure knowledge than for questions about implementation of recommended practices or the use of modern inputs such as inorganic fertilizer or improved seed. It is reassuring that there is consistency between effects found on questions that are more or less prone to experimenter demand effect. In other words, if we would have found that our interventions did not result in a change in knowledge related to optimal plant spacing, yet farmers report that they did use optimal plant spacing on their plots, we would be more worried that the latter effect was driven by experimenter demand effects.

Third, as we will report in the next section, fertilizer adoption, an outcome prone to experimenter demand effects, seemed to increase particularly for treated farmers that live close to an agro-input dealer. This finding reduces the possibility that results are driven by misreporting related to experimenter demand effects, as this would mean that households that have better access to improved inputs strategically decide to report their answers differently than households that have less access to inputs.

5.3 Heterogeneous treatment effects

In this section, we explore potential heterogeneity in the treatment effects. We do this by running the regression model 1 again, but only for a particular group of farmers as determined by their baseline characteristics.

First, we test if treatment effects differ with the education levels of farmers. We mentioned in the introduction that video may be particularly effective in transferring information to low educated and illiterate farmer. Therefore, we reran model 1, but only for farmers that did not finish primary schooling (which is about 65 percent of farmers in our sample). In Appendix Table A.10, which corresponds to Table 2 for the full sample, we see that the increase in knowledge about optimal spacing and seed rate, and to a lesser extent about the benefits of combining inputs, is indeed higher among lower educated farmers.

Farmers are unlikely to adopt a particular modern input if they lack information about its existence, use and benefits. However, once farmers have access to information, they also need to be able to obtain the inputs at a reasonable cost. We therefore also look at how treatment effects vary with distance to an agro-input dealer. Appendix Table A.11 shows regressions similar to those reported in Table 4, but now only for the subset of farmers that live relatively close to an agro-input dealer (within a 5 km radius, corresponding to about two thirds of all farmers in our sample). We find that the video treatment effect for the likelihood that farmers report using urea is now 2.1 percentage points higher. For organic fertilizer, the coefficient estimate is similar to the one obtained for the full sample. Also for hybrid seed, we find that the effect of the IVR encouragement is 1.4 percentage points higher among farmers that live relatively close to an agro-input dealer.

In sub-section 5.1, we already looked at the narrower effect of IVR for farmers that actually called in. However, also for the additional SMS treatment, one would probably only expect to see an effect for households that have a mobile phone. Averaging outcomes over all household may dilute the treatment effect, making it more difficult to detect a significant difference between the treatment group and control group. We thus estimated equation 1 again, but only for households that report that they own a mobile phone. However, restricting the sample in this way did not alter the findings reported in the previous section.

5.4 Attrition

Following implementation of the field experiment, 342 households (or 8.63 percent of the sample) could not be tracked or persuaded to complete the endline survey. Given the relative short time between baseline and endline, this is quite large. Attrition was 7.03 percent in the control group; 8.74 percent in the group that was shown a video; 8.90 percent in the group that was shown a video and received the IVR encouragement; and 7.45 percent in the group that also received an SMS in addition to the IVR encouragement and the video.

Table 6 presents a summary of a series of tests we did to investigate differential attrition. They are obtained from a series of regressions where an indicator of attrition is regressed upon treatment indicators and interactions with baseline characteristics. The first row looks at differential attrition among treatment groups. The first column compares attrition between the control group and households that received the video intervention. A t-test shows no significant difference in attrition between these two groups. The second column compares

Table 6: Differential attrition and correlation with baseline characteristics

	video t-test	+IVR t-test	+SMS t-test	joint F-test
treatments	0.972	0.691	-1.541	1.956
	(0.331)	(0.490)	(0.124)	(0.118)
Maize yield (kg/ac)	0.626	0.087	-1.274	0.750
	(0.531)	(0.931)	(0.203)	(0.522)
Age of HH head (years)	0.904	0.531	0.240	0.255
	(0.366)	(0.595)	(0.810)	(0.858)
HH head finshed primary school	1.222	1.293	0.327	0.858
	(0.222)	(0.196)	(0.744)	(0.462)
HH size	0.467	0.539	1.811	1.066
	(0.640)	(0.590)	(0.070)	(0.362)
Number of bedrooms	0.321	-0.860	0.907	1.347
	(0.748)	(0.390)	(0.365)	(0.257)
Access to extension last year	-1.765	-2.286	-0.987	2.098
	(0.078)	(0.022)	(0.324)	(0.098)
Has used fertilizer last season	-0.698	-0.552	1.354	1.395
	(0.486)	(0.581)	(0.176)	(0.242)
Has used improved seed last season	0.150	0.349	0.926	0.301
	(0.881)	(0.727)	(0.354)	(0.824)
Distance nearest agro input shop (km)	-0.448	-1.788	-0.829	1.021
	(0.654)	(0.074)	(0.407)	(0.382)
HH owns mobile phone	0.096	0.894	1.385	0.684
	(0.924)	(0.371)	(0.166)	(0.562)
HH has access to a mobile phone	-0.474	0.645	0.894	0.456
	(0.636)	(0.519)	(0.371)	(0.713)
joint (F-test)	0.782	1.212	1.137	0.926
	(0.658)	(0.273)	(0.327)	(0.589)

Note: All entries are t-tests, except for the last column and the last row, where F-tests are reported for the joint tests. Corresponding p-values in brackets below. Tests are derived from a linear probability models with a binary indicator of attrition as the dependent variable. The first row tests differential attrition rates for each treatment seperately: the video intervention (column 1), the incremental IVR encouragement (column 2) and the additional SMS treatment (column 3). The last column perfoms a joint test of differential attrition on the 3 treatments. Subsequent rows test differential attrition rates for interactions between each baseline variable indicated to the left and each treatment indicator seperately (columns 1, 2 and 3) and jointly (column 4). Last row tests differential attrition rates for intractions between all baseline variables jointly and each treatment indicator seperately (columns 1, 2 and 3) and all treatments jointly (column 4).

households that (also) received the encouragement treatment to those that did not (the control group and the video only group). Also here, there is no difference in attrition. We then compare attrition among the group that was allocated to the SMS treatment to those that were not, and again find no significant difference. In the final column, we implement a joint test of differential attrition across the treatment groups. We do so by running a regression of the attrition indicator on dummy variables for the three treatments and test if all estimated coefficients are jointly zero. An F-test shows we can not reject the hypothesis of no differential attrition.

We further investigate if attrition rates are correlated to baseline characteristics and whether this correlation differs by treatment group. Here, the base specification regresses an indicator of attrition on a treatment indicator, the baseline characteristic under consideration, and the interaction between the treatment indicator and the baseline characteristic. We then test if the interaction between treatment and baseline characteristic is significantly different from zero using a t-test. For instance in the first column of the second row, we do not find that attrition rates are related to baseline yields among households that received the video intervention. In the second column of the second row, we also confirm that attrition rates are unrelated to baseline yields among households that received the IVR encouragement. The third column implements a similar test for the SMS subgroup. Finally, in the last column, we test if coefficients on yield interacted with all treatment dummies is jointly different from zero using an F-test. Also here, balance can not be rejected. These series of tests are repeated for each of the baseline characteristics that were included in Table 1. In the bottom rows of Table 6, results for joint tests for all the baseline characteristics and the interaction with the video dummy (column 1), with the IVR dummy (column 2), with the SMS dummy (column 3) and with all three treatment dummies jointly (column 4) are reported. Overall, we find that attrition is unrelated to the treatment and also unrelated to baseline characteristics, except perhaps for having received extension at baseline.

Finally, we also estimate Manski bounds to get an idea of the potential impact of attrition

(Manski, 1989). Results, presented in Appendix Tables A.12 to A.15, provide upper and lower bounds for all results presented in Tables 2 through 5. Generally, the bounds are narrow and confirm our findings that videos increase knowledge and practices about optimal spacing, the use of both organic and inorganic fertilizer, and yields. For the latter, the bounds are wide. However, Manski bounds are known to become less informative when the range of possible outcomes increases (Gerber and Green, 2012).

6 Cost-effectiveness

Cost-effectiveness and scalability are often major selling points for interventions such as the ones being tested. While we did not collect detailed information on prices paid for inputs or the cost of labour, we can use the estimates above together with aggregate price data and some assumptions in a series of back-of-the-envelope cost and benefit calculations. We first check if the video intervention affected profitability of the average farmer and then compare the total cost of the intervention to the total benefit derived by the farmers in our study.

In our sample, a bag of 100 kg of maize was sold at a median price of UGX 60,000. We have seen that a control household reported yields of 430 kg per acre, with a corresponding value of UGX 258,000. In the sub-sample that received the video treatment, yields increased to 475 kg per acre, corresponding to UGX 285,000. This means a difference in income of UGX 27,000 per acre, or about 7.7 USD.

From this, we subtract the cost of inputs. In the intervention, we recommended two hybrid seed types, Longe 10H and UH5354 (commonly known as Bazooka). At the time of the experiment, Longe 10H sold for UGX 6,000 per kg, while Bazooka costed UGX 8,500 per kg. However, the data shows that the use of Bazooka was marginal and not correlated to the treatment. We will therefor use only the price of Longe 10H in the cost calculations. We further recommended two open-pollinated varieties: Longe 5 and Longe 4. Among these two, Longe 5 is the most common variety. Both types costed about UGX 3,000 per kg. A farmer needs about 8 kg of seed to plant one acre. Inorganic fertilizers are probably the largest cost. The retail price of 1 kg of urea was about UGX 2,500, while DAP costed UGX 3,000 per kilo. We recommended using 60 kg of both DAP and Urea on one acre. We assume that organic fertilizer is free, but may increase labour cost (see below). The spacing and seed rate we recommend in the intervention is unlikely to increase the costs of seed. We recommend a spacing of 75cm x 30cm with one seeds per hill. Most farmers would use 75cm x 60cm with two seeds per hill, leading to the same amount of seed needed per unit of land. We thus simply multiply the cost of these inputs by the likelihood that they were applied in both control and treatment group (Table 4) and subtract this from the income obtained from maize. Doing so actually increases the difference in income between treatment and control somewhat, as the likelihood that farmers use the more expensive fertilizer DAP reduced somewhat, while the likelihood that farmers use Urea increased.

Changes in the cost of labour are harder to value. Table 3 shows an increase in the practice of removing striga early on, which is likely to increase labour. The new spacing recommendation also means more hills are needed, which may also have an impact on labour, as does the increased use of organic fertilizer. At the same time, in our endline data, we do not find that the video treatment is significantly correlated to the time spent on preparing the land (which includes application of inorganic fertilizer), to time spend on weeding, nor to the likelihood that labor is hired in. In addition, labour is very cheap (6,000 per day). Valuing work related to organic fertilizer adoption at 3 days, the adoption of the new planting method at 2 days and the work for weeding at 10 days (which is the time needed to weed one acre), the difference in profit between treatment and control reduces to 22,464 or about 6.5 USD.

The intervention costed close to USD 37,000. Almost 40 percent of this are fixed costs such as the production of the video (USD 6,300) and the cost of procuring 20 tablets at a total cost of USD 5,600. We also needed to train the enumerators at a total cost of USD 2,224. Variable costs are estimated to be about USD 2.77 for a single screening to an average farmer in the area. This includes time for the personnel showing the video and supervision time, car hire with driver, and fuel needed to reach the households. As a result, the intervention as implemented would only break even at about 15,000 observations. If the intervention is rolled out to all 360,000 households in the 5 districts where the intervention was piloted, the internal rate of return would be about 16 %[13].

7 Conclusion

In this study, we evaluated comprehensive ICT-mediated agricultural extension approach consisting of three components. The approach entails providing information through appealing video messages animated by farmer-actors who farmers can relate to. While appealing because of its combination of both audio and visual information, the approach is also somewhat supply-driven, assigning farmers to a passive role as the recipient of information. Furthermore, in our context, the information was shown to the farmers before the start of the agricultural season individually on tablets, hence farmers may forget particular details of what was shown. We therefore add an additional component–an interactive voice response (IVR) service–that allows the farmer to play a more active role in information acquisition by allowing the farmer to call into a system that offers menu-based choices leading to pre-recorded message. Finally, constraints to intensification may be less related to information inefficiencies, but more of a behavioral nature. Also here, ICTs have been proven effective and a third component consists of a series of short message services (SMS) messages that remind the farmer of particular key inputs or practices, information on which was provided in the video and can be consulted through the IVR.

We tested the approach in an incremental fashion using a field experiment that involved nearly 4,000 smallholder maize farmers in eastern Uganda. To assess the effectiveness of the first channel, we compared outcomes of a random subset of farmers that was shown an informational video to a random subset of farmers that was shown a placebo video. From this initial treatment group, two-thirds of the farmers that were shown the video were randomly assigned to receive an IVR starter kit which encouraged them call into the IVR service to obtain information on maize cultivation that was consistent with the video's content. From this second treatment group, half were randomly assigned to receive a series of eight time-sensitive SMS reminders related to the recommended practices and technologies, along with a reminder to use the IVR service to obtain additional information. The design of this experiment allowed us to estimate the effect of the video treatment as well as the additional effects of the IVR encouragement and SMS treatments. Effectiveness was measured in terms of knowledge gained, practices and technologies adopted, and production increased.

Findings indicate that in our study site and context, video-enabled agricultural extension approaches affect a range of outcomes. Showing agricultural information videos to maize farmers increased knowledge outcomes, particularly on new practices and technologies, and increased the adoption of recommended practices, particularly those that were new and otherwise unknown to farmers. Videos also led to increased use of certain types of fertilizers (urea and organic). As a result, farmers that were shown agricultural information videos increased their maize yields by 10.5 percent. The IVR treatment offered in addition to the video treatment did not seem to additionally increase knowledge or adoption outcomes, although there is some evidence to suggest that farmers who received the IVR encouragement were more likely to use hybrid maize seed. We found no additional effect of being offered IVR on production. The SMS reminders provided in addition to the video treatment and IVR encouragement also did not have any additional effect.

While we establish clear effects from the video intervention, it is less clear what we can learn from the null results for the additional treatments. In other studies, IVR or hot-lines have been shown to have impact (eg. Cole and Fernando, 2016), and SMS is successfully used in a variety of contexts (eg. Fabregas et al., 2019). Therefore, the lack of impact may be specific to the nature of the design and results may be quite different in, for instance, a parallel design.

But even in the narrow context of our experiment, where an effort was made to study particular characteristics of the interventions such as the demand driven nature of IVR or the ability of SMS to make information more salient, it is not clear if the lack of impact should be taken to mean much. For instance, in Sub-section 5.1 we argue that the low take-up of the IVR is likely to reduce power too much to detect any reasonable effect. Maybe, with some additional promotion of the service, positive effects would have been obtained. The SMS intervention also has its issues. Here, even after restricting to farmers that own a mobile phone, the implicit assumption that everyone with a mobile phone also reads and internalizes the messages may be too optimistic. Furthermore, we found it difficult to get the timing of the messages right. While we tried to avoid excessive difference in agro-ecological conditions, we still encountered situations where farmers had planted much earlier than in other areas due to spatial heterogeneity in the onset of the rains. As a result, some farmers will have received the SMS message on fertilizer application too early and others too late. Therefore, care should be taken when interpreting the results.

Notes

[1]This study is part of a larger study that also looked at the role of gender in video mediated agricultural extension. The overall study took the form of a 3^3 factorial design (plus a separate pure control group), where one factor corresponds to the information technology and the other two factors varied the gender of the person to whom the video was shown within the household and the gender of the person who provides the information in the video. In this study, we restrict attention to the first factor. More information on the overall study can be found in the pre-analysis plan.

[2]Ex ante, we expected the largest effect size for the video intervention, and power calculations indicated that we only needed about 250 observations in each group to detect this. Much smaller effects were expected from adding the other two technologies (as essentially not new information is given, see section 3), so a larger sample was needed to retain statistical power. Power calculations were bases on an elaborate set of comparisons using different outcomes to power the complete 3^3 factorial design. We used simulation techniques that allowed us to sample from actual data on outcome variables instead of from a theoretical distribution with an assumed mean and standard deviation. Apart from the sample size in the control group,

sample size in other treatment arms are the result of binding constraints for minimal sample size needed to test differences in two other factors of the design. Detailed information on the power calculations can be found in the pre-analysis.

[3]More precisely, and as mentioned in footnote 1, this research was part of a larger research project that also used the video intervention to explore issues related to gender in agricultural extension. Because of this, we also experimentally varied who provided the information in the video (a man alone, a woman alone, or a couple (man+woman)) as well as to whom the video was shown within the household (a man alone, a woman alone, or a couple (man+woman)). In the context of a factorial design with two factors with each 3 levels, this corresponded to 9 treatment combinations. We thus used villages as blocs, and randomly assigned the nine potential treatment combinations to the remaining 9 households in each village. We then added the IVR treatment randomly to 2/3 of the households in each treatment cell. Among those that were allocated the IVR in each treatment cell, we then randomly allocated 1/2 of households to the SMS treatment. As such, the treatment cells created by the interaction of the 2 other factors were used as blocs in the randomization of IVR and SMS treatments. The exact same sampling procedure was used in the permutation algorithm that was used to judge significance through randomization inference.

[4]In particular, the person or persons within the household to whom the video was shown was dictated by one of the other factors in the factorial design, and were either the man co-head within the household alone, the woman co-head within the household alone, or the man and woman co-heads as a couple together. As this factor was orthogonal to the factor corresponding to the information technologies in the factorial design, it does not matter who within the household the video is shown to, and the treatment effect corresponds to the average impact at the household level.

[5]As we found only limited imbalance in baseline covariates in Table 1, we do not include baseline variables as control here. However, we also did the analysis with controls, results of which can be found in Appendix Tables A.1 through A.4. Results are not sensitive to inclusion of baseline variables.

[6]In fact, our pre-analysis plan specifies that we would drop from the analysis variables where 95 percent of outcomes are the same value.

[7]Consistent with this interpretation, we find that among farmers that called the IVR service and selected the topic on seed selection, 38 percent reported that they used hybrid seed. This is only 35 percent among those that called but did not select this topic. However, the difference is not statistically significant.

[8]Farmers may have confused yields with production. Consistent with our recommendation to start small and combine technologies and the results that yield effects are due to producing the same amounts on smaller plots, farmers may indicate that on the plot the same amount of maize was produced when part was left fallow or planted with another crop.

[9] A back-of-the-envelope calculation shows that the minimum detectable effect (MDE) size for maize yields in the original IVR design would be about 6.4 percent. With only 8.9 percent compliance, the MDE increases to 71.6 percent.

[10] Fabregas et al. (2019) also find very low uptake of similar demand driven extension technologies in their analysis of different ICT enabled extension programmes in Kenya and Rwanda. In one experiment where farmers were offered to receive a call from an extension agent, only 8% of farmers requested a phone call during planting season. In another project, farmers also had access to a toll-free number, but only about 1% of treated farmers (35 callers) used it. Cole and Fernando (2016) find 88 percent of farmers called a hotline, but these use rates were attained only after 2 years of intensive exposure to the system using bi-weekly reminders and on a study population of cotton farmers that expressed willingness to participate and owned a mobile phone.

[11] The fact that 430 unique calls to the system were recorded, representing about 18 percent of encouraged households, confirms this suspicion.

[12] A similar concern applies to our indicator of take-up of to SMS treatment. Here, however, we fear that compliance is overestimated and so IV estimates will result in a downward bias of the impact of the treatment on compliers. That is, our indicator of compliance is again derived from the system logs and simply looks at message delivery to the intended phone. Probably not all farmers also opened the messages and read them. But the problem is likely to be less severe here, given a stronger first stage and a likely smaller difference between measured compliance and real compliance.

[13] It may be possible to reduce variable costs considerably. The largest component of the variable cost was the cost of the person showing the videos to individual households. Currently, an extension worker with a bachelor's degree costs about the same of what we paid our enumerators (UGX 100,000 per day). One may argue that one does not need to have a university degree to show a video, in which case extension workers with only a diploma can be used at roughly UGX 77,000 per day. This would bring the variable cost down to about USD 2.36 for a single screening to the average farmer. Other cost savings may be obtained by showing videos to groups of farmers instead of individually, or direct streaming of videos to devices of farmers. However, this touches upon potentially important design features of the intervention than may alter outcomes, and as such require additional testing.

References

Abay, K. A., G. Blalock, and G. Berhane. 2017. “Locus of control and technology adoption in developing country agriculture: Evidence from Ethiopia.” *Journal of Economic Behavior & Organization* 143 (C): 98â115.

Aker, J. C. 2011. “Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries.” *Agricultural Economics* 42 (6): 631â647.

Anderson, M. L. 2008. “Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects.” *Journal of the American Statistical Association* 103 (484): 1481â1495.

Angrist, J. D. and J.-S. Pischke. 2008. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press.

Ashraf, N., X. Gine, and D. Karlan. 2009. “Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya.” *American Journal of Agricultural Economics* 91 (4): 973.

Benin, S., E. Nkonya, G. Okecho, J. Randriamamonjy, E. Kato, G. Lubade, and M. Kyotalimye. 2011. “Returns to spending on agricultural extension: the case of the National Agricultural Advisory Services (NAADS) program of Uganda.” *Agricultural Economics* 42 (2): 249â267.

BenYishay, A. and A. M. Mobarak. 2018. “Social learning and incentives for experimentation and communication.” *The Review of Economic Studies* 86 (3): 976â1009.

Bernard, T., S. Dercon, K. Orkin, and A. Seyoum Taffesse. 2015. “Will video kill the radio star? Assessing the potential of targeted exposure to role models through video.” *World Bank Economic Review* 29 (sup 1): S226.

Bindlish, V. and R. E. Evenson. 1997. "The impact of T&V extension in Africa: The experience of Kenya and Burkina Faso." *World Bank Research Observer* 6 (2): 183â201.

Bold, T., K. C. Kaizzi, J. Svensson, and D. Yanagizawa-Drott. 2017. "Lemon Technologies and Adoption: Measurement, Theory and Evidence from Agricultural Markets in Uganda*." *The Quarterly Journal of Economics* 132 (3): 1055â1100.

Bulte, E., G. Beekman, S. Di Falco, J. Hella, and P. Lei. 2014. "Behavioral responses and the impact of new agricultural technologies: Evidence from a double-blind field experiment in Tanzania." *American Journal of Agricultural Economics* 96 (3): 813.

Casaburi, L., M. Kremer, S. Mullainathan, and R. Ramrattan. 2014. "Harnessing ICT to increase agricultural production: Evidence from Kenya." *Unpublished working paper* .

Cole, S. A. and A. N. Fernando. 2016. *Mobilizing Agricultural Advice: Technology Adoption, Diffusion and Sustainability.* Harvard Business School Working Paper 13-047, Harvard Business School, Cambridge, MA.

de Janvry, A., E. Sadoulet, and T. Suri. 2017. *Handbook of Economic Field Experiments*, vol. 2, chap. Field experiments in developing country agriculture, 427â466. Elsevier.

De Quidt, J., J. Haushofer, and C. Roth. 2018. "Measuring and bounding experimenter demand." *American Economic Review* 108 (11): 3266â3302.

Duflo, E., R. Glennerster, and M. Kremer. 2007. "Using randomization in development economics research: A toolkit." *Handbook of development economics* 4: 3895â3962.

Duflo, E., M. Kremer, and J. Robinson. 2011. "Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya." *American Economic Review* 101: 2350â2390.

Duflo, E., D. Keniston, and T. Suri. 2014. *Diffusion of Technologies within Social Networks: Evidence from a Coffee Training Program in Rwanda.* IGC Working Paper F-4001-RWA-1, International Growth Centre.

Fabregas, R., M. Kremer, M. Lowes, R. On, and G. Zane. 2019. "Can SMS-extension increase farmer experimentation ? Evidence from Six RCTs in East Africa."

Feder, G., R. Murgai, and J. B. Quizon. 2004a. "The acquisition and diffusion of knowledge: The case of pest management training in farmer field schools, Indonesia." *Journal of Agricultural Economics* 55 (2): 221â243.

———. 2004b. "Sending farmers back to school: The impact of farmer field schools in Indonesia." *Applied Economic Perspectives and Policy* 26 (1): 45â62.

Feder, S. A. J. R., Gershon Ganguly. 2006. *The Rise and Fall of Training and Visit Extension: An Asian Mini-Drama with an African Epilogue*. Washington, DC: World Bank.

Fu, X. and S. Akter. 2016. "The impact of mobile phone technology on agricultural extension services delivery: Evidence from India." *Journal of Development Studies* 52 (11): 1561â1576.

Gandhi, R., R. Veeraraghavan, K. Toyama, and V. Ramprasad. 2009. "Digital Green: participatory video and mediated instruction for agricultural extension." *Information Technologies & International Development* 5 (1): ppâ1.

Gerber, A. and D. Green. 2012. *Field Experiments: Design, Analysis, and Interpretation*. W. W. Norton.

Imbens, G. W. and J. D. Angrist. 1994. "Identification and Estimation of Local Average Treatment Effects." *Econometrica* 62 (2): 467â475.

Joughin, J. and A. M. KjÃŠr. 2010. "The politics of agricultural policy reform: the case of Uganda." In "Forum for Development Studies," vol. 37, 61â78. Taylor & Francis.

Karlan, D., R. Osei, I. Osei-Akoto, and C. Udry. 2014. "Agricultural decisions after relaxing credit and risk constraints." *Quarterly Journal of Economics* 129 (2): 597.

Larochelle, C., J. Alwang, E. Travis, V. H. Barrerea, and J. M. Dominguez Andrade. 2019. “Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies.” *Journal of Development Studies* 55 (4): 548â564.

Manski, C. F. 1989. “Anatomy of the selection problem.” *Journal of Human resources* 343â360.

Maredia, M. K., B. Reyes, M. N. Ba, C. L. Dabire, B. Pittendrigh, and J. Bello-Bravo. 2017. “Can mobile phone-based animated videos induce learning and technology adoption among low-literate farmers? A field experiment in Burkina Faso.” *Information Technology for Development* 1â32.

Masset, E. and L. Haddad. 2015. “Does beneficiary farmer feedback improve project performance? An impact study of a participatory monitoring intervention in Mindanao, Philippines.” *Journal of Development Studies* 51 (3): 287â304.

Mummolo, J. and E. Peterson. 2019. “Demand effects in survey experiments: An empirical assessment.” *American Political Science Review* 113 (2): 517â529.

Nakasone, E. and M. Torero. 2016. “A text message away: ICTs as a tool to improve food security.” *Agricultural Economics* 47 (S1): 49â59.

Rwamigisa, P. B., R. Birner, M. N. Mangheni, and A. Semana. 2018. “How to promote institutional reforms in the agricultural sector? A case study of Uganda’s National Agricultural Advisory Services (NAADS).” *Development Policy Review* 36 (5): 607â627.

Stokstad, E. 2017. “New crop pest takes Africa at lightning speed.” *Science* 356 (6337): 473â474.

Sunstein, C. R. 2014. “Nudging: A very short guide.” *Journal of Consumer Policy* 37 (4): 583â588.

Van Campenhout, B. 2017. “There is an app for that? The impact of community knowledge workers in Uganda.” *Information, Communication & Society* 20 (4): 530â550.

Van Campenhout, B., S. Vandevelde, W. Walukano, and P. Van Asten. 2017. “Agricultural extension messages using video on portable devices increased knowledge about seed selection, storage and handling among smallholder potato farmers in southwestern Uganda.” *PLOS ONE* 12 (1): 1â17.

Waddington, H., B. Snilstveit, J. Hombrados, M. Vojtkova, D. Phillips, P. Davies, and H. White. 2014. “Farmer field schools for improving farming practices and farmer outcomes: A systematic review.” *Campbell Systematic Reviews* 6.

Zizzo, D. J. 2010. “Experimenter demand effects in economic experiments.” *Experimental Economics* 13 (1): 75â98.

Appendix

Table A.1: Additional impact of IVR and SMS treatments on knowledge outcomes after controlling for imbalance

	+IVR	p-value	+SMS	p-value	N
Knows optimal spacing (yes=1)	-0.028	0.096	0.013	0.444	3,554
	(0.018)		(0.019)		
Knows inputs best combined (yes=1)	-0.017	0.087	0.009	0.412	3,554
	(0.011)		(0.011)		
Knows optimal time for weeding (yes=1)	0.009	0.338	-0.001	0.902	3,554
	(0.010)		(0.011)		
Knows how to fight armyworm (yes=1)	-0.018	0.526	0.021	0.287	3,554
	(0.019)		(0.020)		
Knowledge index	-0.025	0.211	0.058	0.462	3,554
	(0.025)		(0.026)		

Note: Column 1 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 2; column 3 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 4; sample size is reported in column 5. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design. Additional controls for the IVR treatment are age of household head at baseline, household size at baseline and number of bedrooms at baseline. Additional controls for the SMS treatment are number of bedrooms at baseline.

Table A.2: Additional impact of IVR and SMS treatments on agronomic practices after controlling for imbalance

	+IVR	p-value	+SMS	p-value	N
Planted immediately after start of rains (yes=1)	0.015	0.477	-0.006	0.787	3,438
	(0.021)		(0.022)		
Used spacing of 75cm x 30cm with a reduced seed rate (yes=1)	-0.004	0.746	0.012	0.288	3,438
	(0.012)		(0.012)		
Removed striga early on (yes=1)	-0.006	0.802	0.022	0.195	3,438
	(0.019)		(0.020)		
First weeding after 18-20 days (yes=1)	0.007	0.729	-0.001	0.975	3,438
	(0.021)		(0.022)		
Recommended practices index	0.011	0.657	0.038	0.382	3,438
	(0.022)		(0.023)		

Note: Column 1 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 2; column 3 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 4; sample size is reported in column 5. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design. Additional controls for the IVR treatment are age of household head at baseline, household size at baseline and number of bedrooms at baseline. Additional controls for the SMS treatment are number of bedrooms at baseline.

Table A.3: Additional impact of IVR and SMS treatments on on fertilizer and improved seed use after controlling for imbalance

	+IVR	p-value	+SMS	p-value	N
			fertilizer use		
Used DAP/NPK on at least one plot? (yes=1)	0.018	0.261	-0.006	0.702	3,498
	(0.017)		(0.018)		
Used Urea on at least one plot? (yes=1)	0.014	0.256	-0.024	0.060	3,498
	(0.012)		(0.013)		
Used organic fertilizer on at least one plot? (yes=1)	-0.037**	0.021	0.031	0.062	3,498
	(0.017)		(0.018)		
Fertilizer index	-0.005	0.837	0.014	0.931	3,498
	(0.025)		(0.026)		
			seed use		
Used hybrid maize seed on at least one plot? (yes=1)	0.041**	0.031	-0.048	0.010	3,498
	(0.019)		(0.020)		
Used Open Polinated Varieties on at least one plot? (yes=1)	0.010	0.558	0.026	0.396	3,498
	(0.019)		(0.020)		
Seed index	0.060**	0.029	0.013	0.466	3,498
	(0.028)		(0.029)		

Note: Column 1 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 2; column 3 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 4; sample size is reported in column 5. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design. Additional controls for the IVR treatment are age of household head at baseline, household size at baseline and number of bedrooms at baseline. Additional controls for the SMS treatment are number of bedrooms at baseline.

Table A.4: Additional impact of IVR and SMS treatments on production after controlling for imbalance

	+IVR	p-value	+SMS	p-value	N
Maize production (log(kg))	0.040	0.336	0.042	0.309	3,282
	(0.035)		(0.036)		
Maize area (log(acre))	-0.020	0.457	0.028	0.293	3,271
	(0.026)		(0.028)		
Maize yield (log(kg/acre))	0.038	0.249	0.004	0.883	3,244
	0.029		0.030		
Yield better than normal (yes=1)	0.006	0.787	0.030	0.205	3,498
	(0.021)		(0.022)		
Labour (log(days))	-0.013	0.640	0.041	0.085	3,312
	0.025		0.026		
Labour productivity (log(kg/days))	0.067	0.084	-0.008	0.757	3,280
	(0.033)		(0.035)		
Production index	0.008	0.464	0.025	0.520	3,241
	(0.016)		(0.016)		

Note: Column 1 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 2; column 3 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 4; sample size is reported in column 5. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design. Additional controls for the IVR treatment are age of household head at baseline, household size at baseline and number of bedrooms at baseline. Additional controls for the SMS treatment are number of bedrooms at baseline.

Table A.5: Determinants of IVR uptake

	Dependent variable: called
Allocated to SMS treatment	0.057***
	(0.013)
HH has access to a mobile phone	0.058**
	(0.028)
HH owns mobile phone	0.042*
	(0.025)
Maize yield (kg/ac)	0.00000
	(0.00002)
Age of HH head (years)	−0.001
	(0.0005)
HH head finshed primary school	0.006
	(0.006)
HH size	0.002
	(0.002)
Number of bedrooms	−0.003
	(0.006)
Access to extension last year	0.001
	(0.020)
Has used fertilizer last season	−0.075
	(0.131)
Has used improved seed last season	−0.089
	(0.131)
Distance nearest agro input shop (km)	0.001
	(0.001)
Constant	0.058
	(0.136)
Observations	2,180
R^2	0.040
Adjusted R^2	0.033
Residual Std. Error	0.292 (df = 2163)
F Statistic	5.613*** (df = 16; 2163)

Note: *p<0.1; **p<0.05; ***p<0.01

Table A.6: 2SLS estimates of impact of IVR treatment on household level knowledge

	Mean	+IVR	p-value	N
Knows optimal spacing (yes=1)	0.160	-0.360	0.306	3,619
	(0.367)	(0.351)		
Knows inputs best combined (yes=1)	0.908	-0.331	0.115	3,619
	(0.290)	(0.210)		
Knows optimal time for weeding (yes=1)	0.954	0.178	0.350	3,619
	(0.210)	(0.191)		
Knows how to fight armyworm (yes=1)	0.336	-0.286	0.431	3,619
	(0.473)	(0.363)		
Knowledge index	-0.077	-0.396	0.376	3,619
	(0.562)	(0.473)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 3; sample size is reported in column 4. All specifications control for the other orthogonal factors in the factorial design.

Table A.7: 2SLS estimates of impact of IVR treatment on agronomic practices

	Mean	+IVR	p-value	N
Planted immediately after start of rains (yes=1)	0.370	0.163	0.677	3,500
	(0.484)	(0.391)		
Used spacing of 75cm x 30cm with a reduced seed rate (yes=1)	0.026	-0.089	0.670	3,560
	(0.158)	(0.210)		
Removed striga early on (yes=1)	0.685	-0.170	0.617	3,560
	(0.465)	(0.339)		
First weeding after 18-20 days (yes=1)	0.426	0.228	0.552	3,560
	(0.495)	(0.383)		
Recommended practices index	-0.086	0.102	0.804	3,500
	(0.478)	(0.411)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 3; sample size is reported in column 4. All specifications control for the other orthogonal factors in the factorial design.

Table A.8: 2SLS estimates of impact of IVR treatment on fertilizer and improved seed use

	Mean	+IVR	p-value	N
		fertilizer use		
Used DAP/NPK on at least one plot? (yes=1)	0.264	0.393	0.228	3,560
	(0.442)	(0.325)		
Used urea on at least one plot? (yes=1)	0.051	0.225	0.320	3,560
	(0.221)	(0.226)		
Used organic fertilizer on at least one plot? (yes=1)	0.157	-0.704**	0.037	3,560
	(0.365)	(0.337)		
Fertilizer index	-0.057	-0.078	0.846	3,560
	(0.547)	(0.443)		
		seed use		
Used hybrid maize seed on at least one plot? (yes=1)	0.289	0.732**	0.046	3,560
	(0.454)	(0.367)		
Used Open Polinated Varieties on at least one plot? (yes=1)	0.302	0.164	0.635	3,560
	(0.460)	(0.345)		
Seed index	0.032	0.242	0.605	3,560
	(0.700)	(0.447)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 3; sample size is reported in column 4. All specifications control for the other orthogonal factors in the factorial design. ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively.

Table A.9: 2SLS estimates of impact of IVR treatment on production

	Mean	+IVR	p-value	N
Maize production (log(kg))	5.814	0.912	0.173	3,344
	(0.765)	(0.670)		
Maize area (log(acre))	0.018	-0.240	0.614	3,341
	(0.580)	(0.476)		
Maize yield (log(kg/acre))	5.850	0.690	0.224	3,302
	(0.658)	(0.568)		
Yield better than normal (yes=1)	0.387	0.008	0.983	3,560
	(0.488)	(0.374)		
Labour (log(days))	4.132	-0.056	0.895	3,370
	(0.577)	(0.421)		
Labour productivity (log(kg/days))	1.650	1.185	0.076	3,341
	(0.720)	(0.667)		
Production index	-0.053	0.159	0.625	3,302
	(0.365)	(0.297)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 3; sample size is reported in column 4. All specifications control for the other orthogonal factors in the factorial design.

Table A.10: Impact of ICT treatments on knowledge outcomes for low educated farmers

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
Knows optimal spacing (yes=1)	0.097	0.172***	0.000	-0.021	0.269	0.012	0.562	2,317
	(0.297)	(0.037)		(0.022)		(0.023)		
Knows inputs best combined (yes=1)	0.882	0.063**	0.014	-0.015	0.230	0.008	0.651	2,317
	(0.324)	(0.024)		(0.014)		(0.015)		
Knows optimal time for weeding (yes=1)	0.944	-0.008	0.706	0.010	0.360	0.000	0.995	2,317
	(0.230)	(0.021)		(0.012)		(0.013)		
Knows how to fight armyworm (yes=1)	0.271	0.027	0.482	-0.017	0.703	0.041	0.237	2,317
	(0.446)	(0.039)		(0.023)		(0.025)		
Knowledge index	-0.137	0.153***	0.001	-0.022	0.498	0.068	0.681	2,317
	(0.546)	(0.053)		(0.031)		(0.033)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

Table A.11: Impact of ICT treatments on fertilizer and improved seed use for farmers close to agro-input shop

	Mean	Video	p-value	+IVR	p-value	+SMS	p-value	N
				fertilizer use				
Used DAP/NPK on at least one plot? (yes=1)	0.285	-0.048	0.148	0.008	0.717	-0.004	0.844	2,436
	(0.453)	(0.036)		(0.021)		(0.023)		
Used Urea on at least one plot? (yes=1)	0.038	0.070**	0.007	0.005	0.715	-0.026	0.104	2,436
	(0.192)	(0.024)		(0.014)		(0.015)		
Used organic fertilizer on at least one plot? (yes=1)	0.165	0.073*	0.036	-0.025	0.242	0.011	0.564	2,436
	(0.372)	(0.034)		(0.021)		(0.022)		
Fertilizer index	-0.058	0.082	0.110	-0.011	0.728	-0.001	0.509	2,436
	(0.534)	(0.048)		(0.029)		(0.031)		
				improved seed use				
Used hybrid maize seed on at least one plot? (yes=1) hybrid	0.297	-0.011	0.768	0.054**	0.013	-0.034	0.146	2,436
	(0.459)	(0.038)		(0.023)		(0.024)		
Used Open Polinated Varieties on at least one plot? (yes=1)	0.291	-0.022	0.538	0.020	0.332	0.000	0.986	2,436
	(0.456)	(0.037)		(0.022)		(0.024)		
Seed index	0.030	-0.072	0.481	0.082***	0.010	0.004	0.292	2,436
	(0.678)	(0.056)		(0.033)		(0.035)		

Note: In the first column, means (and standard deviations) in the control group are presented for each variable. Column 2 reports differences between placebo and video treatment (and standard error) with its corresponding p-value in column 3; column 4 reports differences between video only and video+ivr (and standard error) with its corresponding p-value in column 5; column 6 reports differences between video+ivr and video+ivr+SMS (and standard error) with its corresponding p-value in column 7; sample size is reported in column 8. Reported p-values are based on randomization inference (10,000 permutations); ***, ** and * denote that the difference is signficant at the 1, 5 and 10 percent level, respectively, after correcting for multiple hypothesis testing using a family-wise sharp null (10,000 permutations). All specifications control for the other orthogonal factors in the factorial design.

Table A.12: Attrition bounds for knowledge outcomes

	video		*IVR*		*SMS*	
	[Min	Max]	[Min	Max]	[Min	Max]
Knows optimal spacing (yes=1)	0.112	0.194	-0.026	-0.014	0.017	-0.007
	(0.029)	(0.032)	(0.017)	(0.018)	(0.018)	(0.020)
Knows inputs best combined (yes=1)	-0.041	0.042	-0.027	-0.014	0.031	0.006
	(0.024)	(0.017)	(0.014)	(0.010)	(0.015)	(0.010)
Knows optimal time for weeding (yes=1)	-0.095	-0.012	-0.002	0.011	0.021	-0.003
	(0.023)	(0.016)	(0.014)	(0.009)	(0.014)	(0.010)
Knows how to fight armyworm (yes=1)	-0.043	0.040	-0.020	-0.007	0.025	0.001
	(0.031)	(0.033)	(0.018)	(0.019)	(0.019)	(0.020)
Knowledge index	-0.031	0.134	-0.049	-0.013	0.085	0.037
	(0.049)	(0.042)	(0.028)	(0.025)	(0.030)	(0.026)

Note: Column 1 reports differences between placebo and video treatment (and standard error between brackets below) for the outcome indicated to the left after all missing values due to attrition have been replaced by the minimum value of the outcome indicated to the left; Column 2reports differences between placebo and video treatment (and standard error) for the outcome after all missing values due to attrition have been replaced by the maximum value of the outcome; columns 3 and 4 report corresponding estimates (and standard error below) for differences between video only and video+ivr; columns 5 and 6 report corresponding estimates (and standard error below) for differences between video+ivr and video+ivr+SMS. All specifications control for the other orthogonal factors in the factorial design. For indices, missings were replaced in the variables that constitute the components of the index before the index was computed, so the bounds do not necessarily include the estimated coefficient.

Table A.13: Attrition bounds for recommended practices

	video		*IVR*		*SMS*	
	[Min	Max]	[Min	Max]	[Min	Max]
Planted immediately after start of rains (yes=1)	-0.046	0.058	0.007	0.025	0.002	-0.017
	(0.032)	(0.034)	(0.019)	(0.020)	(0.020)	(0.021)
Used spacing of 75cm x 30cm with a reduced seed rate (yes=1)	0.056	0.147	-0.005	0.017	0.013	-0.015
(0.018)	(0.026)	(0.010)	(0.015)	(0.011)	(0.016)	
Removed striga early on (yes=1)	-0.012	0.079	-0.021	0.002	0.042	0.013
	(0.033)	(0.029)	(0.019)	(0.017)	(0.020)	(0.018)
First weeding after 18-20 days (yes=1)	-0.022	0.069	0.000	0.022	0.010	-0.018
	(0.034)	(0.035)	(0.019)	(0.020)	(0.021)	(0.021)
Recommended practices index	0.000	0.182	-0.012	0.035	0.059	-0.002
	(0.038)	(0.042)	(0.022)	(0.024)	(0.023)	(0.025)

Note: Column 1 reports differences between placebo and video treatment (and standard error between brackets below) for the outcome indicated to the left after all missing values due to attrition have been replaced by the minimum value of the outcome indicated to the left; Column 2reports differences between placebo and video treatment (and standard error) for the outcome after all missing values due to attrition have been replaced by the maximum value of the outcome; columns 3 and 4 report corresponding estimates (and standard error below) for differences between video only and video+ivr; columns 5 and 6 report corresponding estimates (and standard error below) for differences between video+ivr and video+ivr+SMS. All specifications control for the other orthogonal factors in the factorial design. For indices, missings were replaced in the variables that constitute the components of the index before the index was computed, so the bounds do not necessarily include the estimated coefficient.

Table A.14: Attrition bounds for inputs

	video		*IVR*		*SMS*	
	[Min	Max]	[Min	Max]	[Min	Max]
			fertilizer use			
Used DAP/NPK on at least one plot? (yes=1)	-0.062	0.030	0.013	0.035	-0.001	-0.030
	(0.028)	(0.031)	(0.016)	(0.018)	(0.017)	(0.019)
Used Urea on at least one plot? (yes=1)	0.040	0.132	0.010	0.033	-0.019	-0.048
	(0.019)	(0.026)	(0.011)	(0.015)	(0.012)	(0.016)
Used organic fertilizer on at least one plot? (yes=1)	0.052	0.144	-0.038	-0.015	0.034	0.006
	(0.027)	(0.031)	(0.016)	(0.018)	(0.017)	(0.019)
Fertilizer index	0.026	0.223	-0.014	0.036	0.026	-0.040
	(0.041)	(0.050)	(0.024)	(0.029)	(0.025)	(0.030)
			seed use			
Used hybrid maize seed on at least one plot? (yes=1)	0.074	-0.017	0.056	0.033	-0.066	-0.038
	(0.033)	(0.030)	(0.019)	(0.017)	(0.020)	(0.018)
Used Open Polinated Varieties on at least one plot? (yes=1)	0.038	-0.053	0.027	0.004	0.002	0.031
	(0.033)	(0.030)	(0.019)	(0.017)	(0.020)	(0.018)
Seed index	0.088	-0.116	0.086	0.042	-0.034	0.030
	(0.051)	(0.047)	(0.030)	(0.027)	(0.031)	(0.028)

Note: Column 1 reports differences between placebo and video treatment (and standard error between brackets below) for the outcome indicated to the left after all missing values due to attrition have been replaced by the minimum value of the outcome indicated to the left; Column 2reports differences between placebo and video treatment (and standard error) for the outcome after all missing values due to attrition have been replaced by the maximum value of the outcome; columns 3 and 4 report corresponding estimates (and standard error below) for differences between video only and video+ivr; columns 5 and 6 report corresponding estimates (and standard error below) for differences between video+ivr and video+ivr+SMS. All specifications control for the other orthogonal factors in the factorial design. For indices, missings were replaced in the variables that constitute the components of the index before the index was computed, so the bounds do not necessarily include the estimated coefficient.

Table A.15: Attrition bounds for production outcomes

	video		*IVR*		*SMS*	
	[Min	Max]	[Min	Max]	[Min	Max]
Maize production (log(kg))	-0.203	0.128	0.013	0.075	0.094	-0.014
	(0.071)	(0.066)	(0.040)	(0.037)	(0.042)	(0.039)
Maize area (log(acre))	-0.240	0.019	-0.032	0.013	0.064	-0.015
	(0.054)	(0.051)	(0.030)	(0.029)	(0.032)	(0.030)
Maize yield (log(kg/acre))	-0.046	0.227	0.008	0.060	0.050	-0.038
	(0.058)	(0.055)	(0.033)	(0.031)	(0.035)	(0.033)
Yield better than normal (yes=1)	-0.011	0.080	-0.005	0.017	0.040	0.011
	(0.033)	(0.034)	(0.019)	(0.020)	(0.020)	(0.021)
Labour (log(days))	-0.137	0.092	-0.026	0.014	0.074	0.002
	(0.050)	(0.047)	(0.028)	(0.026)	(0.029)	(0.028)
Labour productivity (log(kg/days))	-0.139	0.181	0.034	0.091	0.043	-0.058
	(0.066)	(0.065)	(0.037)	(0.036)	(0.039)	(0.038)
Production index	0.005	0.023	0.046	0.054	0.007	0.003
	(0.024)	(0.026)	(0.014)	(0.015)	(0.015)	(0.016)

Note: Column 1 reports differences between placebo and video treatment (and standard error between brackets below) for the outcome indicated to the left after all missing values due to attrition have been replaced by the minimum value of the outcome indicated to the left; Column 2reports differences between placebo and video treatment (and standard error) for the outcome after all missing values due to attrition have been replaced by the maximum value of the outcome; columns 3 and 4 report corresponding estimates (and standard error below) for differences between video only and video+ivr; columns 5 and 6 report corresponding estimates (and standard error below) for differences between video+ivr and video+ivr+SMS. All specifications control for the other orthogonal factors in the factorial design. For indices, missings were replaced in the variables that constitute the components of the index before the index was computed, so the bounds do not necessarily include the estimated coefficient.