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Problem Definition: Customers and providers alike often consider one-on-one service delivery to be ideal, assuming – perhaps unquestioningly – that devoting individualized attention maximizes customer engagement and improves outcomes. Alternatively, shared service delivery, in which customers are served in batch, may – through the dynamics of group interaction – lead to increased customer engagement. However, the loss of privacy and personal connection in shared delivery models may undermine engagement, and consequently, outcomes. **Academic / Practical Relevance:** The engagement dynamics in one-on-one and shared delivery models have not been rigorously studied. To the extent that shared delivery may result in comparable or better engagement than one-on-one delivery, service providers in a broad array of contexts may be able to create more value for customers by delivering service in batches. **Methodology:** We conducted a randomized controlled trial with 1,000 patients who were undergoing glaucoma treatment over a three-year period at a large eye hospital. Using verbatim and behavioral transcripts from over 20,000 minutes of video recorded during our trial, we examine how shared medical appointments (SMAs) – in which groups of patients with similar conditions meet with a doctor simultaneously, and each receives one-on-one care in turn – impact patients’ engagement during their appointments. **Results:** Patients who experienced SMAs asked 37.2% more questions per minute, made 8.2% more comments per minute, answered 3.6% more questions per minute, and exhibited higher levels of non-verbal engagement across a wide array of measures (attentiveness, positivity, head wobbling or ‘talai tallāṭṭam’ in Tamil – a South Indian gesture to signal agreement or understanding – eye contact and end-of-appointment happiness), relative to patients who attended one-on-one appointments. **Managerial Implications:** These results shed light on the potential for shared service delivery models to increase customer engagement and enhance service performance. **Key words:** customer engagement, shared service delivery, shared medical appointments, healthcare operations

1. Introduction

One-on-one interactions are considered best-in-class in many service settings. We queue for personalized attention at the bank and wait on hold (sometimes for hours) if we run into a technical support issue with our cable or internet. One-on-one service is private and individualized, so intuitively, it seems like it should result in better service outcomes. However, when outcomes are coproduced, customer engagement is required to ensure a high-quality result. If customers are less engaged in one-on-one interactions, share less information about their needs and concerns and absorb less of the service provider's recommendations, one-on-one service delivery may not be optimal.

An alternative approach is shared service delivery, in which customers are served in batches. When customers share similar needs, serving groups of them together can increase each customer's time with the service provider (albeit with others present), and may lead to higher levels of engagement. On the other hand, shared service delivery may decrease engagement, due to a loss of privacy.

The orthodoxy of expecting one-on-one service is perhaps strongest in healthcare, where the doctor-patient relationship is sacrosanct. As patients, we are accustomed to meeting with our doctors individually, in order to receive treatment that is personalized and confidential. At the same time, however, a significant portion of healthcare costs and healthcare system congestion worldwide is attributable to common chronic diseases (Thorpe et al. 2010). For these ailments, routine follow up one-on-one appointments have traditionally played a crucial role in preventing future clinical events that can entail expensive hospitalizations (Yach et al. 2004). Patients' engagement in their own care is critical to the successful management of chronic diseases (Beaglehole et al. 2008), and engagement in the medical appointment itself is a vital first step in achieving better outcomes (James et al. 2013, Volpp and Mohta 2016, Hibbard 2003).

With this backdrop, care providers are experimenting with models of care delivery that can enable effective routine care of chronic diseases. One such model is the shared medical appointment (SMA), in which patients with the same chronic condition meet with the physician in a group, each receiving individualized care in turn, with the other patients in the group present during the interaction. In an SMA, patients can benefit from observing the physician interact with other patients, and from hearing their peers' questions and the physician's responses to them. Patients may also spur one another to engage more deeply. In SMAs, each patient spends more time with the physician by design, albeit alongside other patients. Prior research has shown that more time with the physician increases patient engagement in one-on-one appointments (Kaplan et al. 2016). However, it is an empirical question whether the diminished privacy in SMAs might hinder patient engagement, undermining the quality of care.

We address this question by conducting a randomized controlled trial in the glaucoma clinic of a large eye hospital. With patient consent, we randomly assigned 1,000 patients to receive SMAs (the 'treatment' arm) or traditional one-on-one appointments (the 'control' arm) during four consecutive appointments, scheduled about four months apart. SMAs were designed to have five patients, and actually had 2-6 (see Supplementary Appendix A.1 for a breakdown), due to scheduling constraints. Patients consented to have each appointment videotaped, which enabled an in-depth analysis of how shared delivery affected patient engagement.

Our results suggest that despite the relative lack of privacy, patients in SMAs exhibit *higher levels* of both verbal and non-verbal engagement during their appointments. Consistent with the established evidence base on the positive effect of patient engagement on outcomes, our related research based on the same trial reveals that patients in SMAs additionally exhibit higher levels of learning, satisfaction, and medication compliance (citation withheld for blind peer review; please note that this article has been shared with the DE and AE, who are privy to the authors' names in the review process). To the extent that shared service delivery may increase customer engagement in a context like healthcare, we argue that shared delivery models hold promise for improving

service quality in a broad array of service contexts where customer needs and experiences are similar, and customer engagement is determinative of a successful outcome.

Although the concept of SMAs may seem provocative in a setting like healthcare, shared service delivery models are not without precedent. For example, in education, many researchers have explored the relationship between class size and student achievement; although most empirical studies find that reducing class size improves student outcomes (Schanzenbach 2020, American Federation of Teachers 2015); no research advocates one-on-one service delivery.

Indeed, research suggests that bringing people together in a shared service delivery environment can increase engagement, for a variety of reasons. First, the Köhler effect demonstrates that people may become motivated to work harder in groups, as less capable members of the group, motivated by the presence of others, may choose to expend more effort (Köhler 1926, Kerr et al. 2005). Second, engaging in shared service delivery increases operational transparency. With shared delivery, individual customers have better visibility into the engagement of other customers' in the service process, how customer engagement in the service process affects outcomes, and the service provider's efforts in response to customer engagement. Prior field research, conducted with a municipal government, found that when residents were provided with transparency into the otherwise-hidden work of government to respond to resident service requests (e.g. burned-out streetlights, potholes, graffiti, etc.), they felt more trust in government and more positivity toward themselves for engaging with it, which increased their willingness to engage (Buell et al. 2020). Promoting similar visibility through shared delivery might also increase engagement. Third, successful group interaction rituals can play an important role in promoting a sense of collective happiness and mutual focus of attention (Randall 2004). To the extent that an individual's engagement may be improved through shared service delivery, so too might service quality and long-term cost effectiveness. For example, in healthcare, a growing body of evidence demonstrates that patients who are more actively engaged in their own care tend to be healthier and incur lower long-term costs (James et al. 2013).

1.1. Shared medical appointments

SMAs have been reported to be effective for treating patients with a broad array of chronic conditions (Pastore et al. 2014, Wall-Haas et al. 2012, Sumego and Bronson 2014). Consequently, many service providers including the Cleveland Clinic and Kaiser Permanente have used SMAs successfully for a variety of chronic conditions. However, despite these high-profile adoptions of the practice, many patients and doctors remain wary of SMAs, concerned that a lack of privacy may prevent information sharing related to sensitive medical issues (Petronio 2002), thus reducing patient engagement and compromising long-run outcomes (Volpp and Mohta 2016). There is also a worry that interpersonal communication, which can help in strengthening the doctor-patient relationship, may be awkward in a group setting (Taylor et al. 1979, Arora 2003), which could further compromise engagement and outcomes. Thus, despite evidence in the medical literature that SMAs can improve medical outcomes, there remains a need for rigorous scientific study of patients' experience in shared delivery contexts (Edelman et al. 2012, 2015).

Evidence in non-medical settings suggest that SMAs may have the potential to increase patient engagement. For example, support groups, such as Alcoholics Anonymous and Weight Watchers have had widespread success in facilitating members sharing their experiences and helping one another attain their goals (Tiebout 1944). SMAs, as an alternative to one-on-one appointments, provide a similar platform for doctor-patient interactions. Patients in SMAs have the potential to learn from the doctor and from fellow patients with different levels of disease. For example, by observing other patients who are in more advanced disease states, they may learn firsthand the consequences of not using prescribed medicines, and they may receive useful information through relevant questions asked by other patients. In this way, SMAs may change the boundaries of the patient and provider roles, with the potential to improve performance (Ramdas et al. 2012).

It is difficult to develop an evidence base for the benefits of the group format of shared medical appointments, because building rigorous evidence requires keeping all else equal, including the number of appointments, patient scheduling and balancing patient experiences in both arms in

the context of any needed rescheduling. Also, unlike a new drug, which can be developed in a laboratory, care delivery innovations such as shared medical appointments need to be developed and rigorously tested in clinical settings. These inherent challenges have hindered the rigorous trialing of many facets of SMAs in the past (Ramdas and Darzi 2017). With our empirical design, we work to overcome these challenges, presenting the first randomized controlled trial that directly compares the engagement dynamics in one-on-one appointments and SMAs.

1.2. Research setting

We conducted our study in the glaucoma clinic of the Aravind Eye Hospital (Aravind) in Pondicherry, India. During our study period, our site conducted an average of 978 glaucoma appointments per week, which facilitated both subject recruitment efforts, and the assembly of experimental SMAs.

Glaucoma is an incurable chronic disease that damages the optic nerve and is the second- leading cause of blindness worldwide. It progresses in a relatively consistent fashion across patients, and patient engagement is crucial for its successful management. Patients typically require an appointment every 3-6 months, during which their ophthalmologist checks their in-eye pressure and vision (Boyd 2003), adjusts the strength of their prescribed drops, and if necessary, suggests surgery. These measures help stem the gradual, almost imperceptible progression of the disease.

2. Methods

2.1. Trial design

We conducted our trial from July 12, 2016 to September 10, 2019, with the help of two ophthalmologists and two study coordinators. The study protocol was approved by the institutional review boards of Aravind and the authors' institutions, and was registered at the Clinical Trials Registry in India (CTRI) before data collection commenced.

Since we are aware of no prior work that compares engagement across SMAs and one-on-one appointments, we were unable to use prior effect sizes as a starting point for a sample size calculation. Comparing the knowledge levels and follow-up rates among patients who experienced pilot SMAs (conducted in May and June 2015) and traditional one-on-one appointments, we proposed a

target sample size of 1,000 patients (500 in each condition), which yielded a power of 90% ($\beta = 0.1$) and confidence for detecting differences between sample means of 99% ($\alpha = 0.01$) (Ahn et al. 2014, Altman 1980). Per our protocol, we recalculated the sample size using data from the first month of the trial and the target sample size remained unchanged.

Our study inclusion criteria, developed through collaboration with Aravind, are shown in Supplementary Appendix Table A.2. Of the 1,034 patients who met the inclusion criteria and were invited to participate, 1,000 accepted and provided informed consent. Patient characteristics were substantively similar among those who joined and those who declined to join our study (Table 1).

Table 1 Summary Statistics

	(1)		(2)		(3)	
	Participated		Declined to Join Trial		Differences	
	Mean	SD	Mean	SD	Differences	t-Value
Demographic Variables						
Age	62.04	9.34	62.97	9.76	-0.93	(-0.55)
Proportion of Male Patients	0.60	0.49	0.68	0.47	-0.07	(-0.90)
Urban	0.61	0.49	0.68	0.47	-0.06	(-0.78)
Education	2.57	1.21	2.44	1.05	0.13	(0.69)
Medical Variables:						
Proportion of Glaucoma Types						
Primary Open Angle Glaucoma (POAG)	0.74	0.44	0.76	0.43	-0.02	(-0.33)
Primary Angle Closure Disease (PACD)	0.22	0.42	0.21	0.41	0.02	(0.25)
Ocular Hypertension (OHT)	0.01	0.10	0.00	0.00	0.01***	(3.18)
Pseudoexfoliation Glaucoma (PXF Glaucoma)	0.03	0.16	0.03	0.17	-0.00	(-0.11)
Proportion of Comorbidities						
Diabetes	0.37	0.48	0.35	0.49	0.02	(0.24)
Hypertension	0.36	0.48	0.26	0.45	0.10	(1.28)
Cardiac Disease	0.04	0.19	0.06	0.24	-0.02	(-0.53)
Asthma/Chronic Obstructive Pulmonary Disease (COPD)	0.02	0.14	0.00	0.00	0.02***	(4.40)
Other Chronic Diseases	0.01	0.08	0.00	0.00	0.01***	(2.65)
Observations	1000		34		1034	

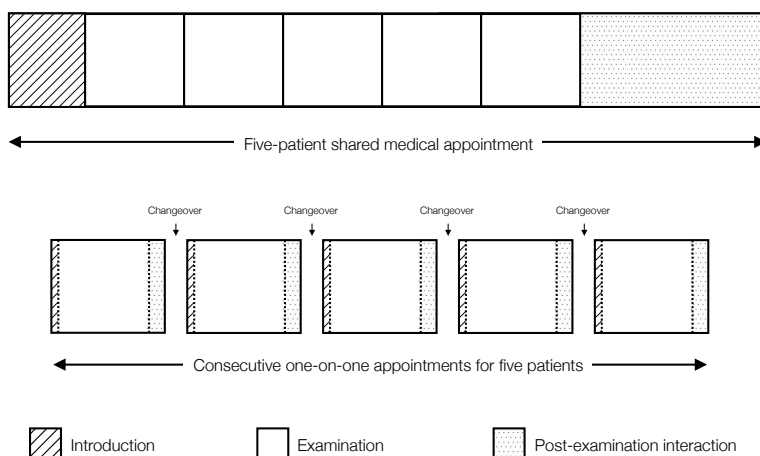
As only 34 out of 1,034 patients declined to join, for some measures there were no cases (and therefore zero variance) in the declining group, resulting, in significant differences across the groups. There were significant differences between both groups in Proportion of Ocular Hypertension, Asthma/Chronic Obstructive Pulmonary Disease (COPD) and Other Chronic Diseases, allowing for differences in variances across groups (all $p < 0.001$). The education variable is scaled as: Illiterate (1); Primary School Education (2); Secondary School Education (3); Undergraduate Education (4); Postgraduate Education (5). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Groups of five patients were randomly assigned to experience SMAs or one-on-one appointments throughout the trial, based on the output of a random number generator. Each enrolled patient was expected to attend a total of four appointments, each scheduled four months apart.

Groups of patients assigned to SMAs received an SMA on each visit, while groups assigned to one-on-one appointments received consecutive appointments with the same doctor (see Figure

1). During their appointments, patients in both arms experienced an eye examination, received recommendations from the doctor, and could ask questions. Consistent with traditional practice at Aravind, appointments in both arms concluded when all patient questions had been addressed. After their appointments, all patients responded to a survey that included questions designed to assess the quality of their experience, and how much they had learned during the appointment. Patients concluded their visit by scheduling their next appointment with a study coordinator.

Figure 1 Structure of a Five-Patient SMA and Consecutive One-on-One Appointments for Five Patients



The structure of a five-patient shared medical appointment and of consecutive one-on-one appointments for five patients are displayed above. Each appointment included an introduction period, an individual examination for each patient, and a period of time dedicated to answering patients' questions. The schematic is drawn to scale based on the average durations observed during our study for five-patient shared medical appointments ($M=18.65$ minutes, $SD=4.04$) and consecutive one-on-one appointments for groups of five patients ($M=15.88$ minutes, $SD=3.54$). The delineations among the introduction, examination, and post-examination interaction are drawn to scale based on mean durations for shared medical appointments. The approximated delineations within one-on-one appointments are also represented in the figure above with dotted lines.

One week, three days, and one day before each scheduled follow-up appointment, a study coordinator phoned patients to remind them about their upcoming appointment and to confirm their availability. If the need arose, the coordinator would reschedule the patient, as well as other enrolled patients to fill in gaps. Importantly, we used identical scheduling and reminder procedures for patients in both arms of the trial to ensure consistent experiences beyond the experimental manipulation.

2.2. Data

Measuring customer engagement is difficult in any service setting. Our body language, how much we speak, and what we say all signal the extent of our underlying engagement. Although asking

people how engaged they were in an interaction can introduce error due to memory lapses and intentional misreporting (Paulhus and Vazire 2007), having a researcher physically present to record engagement can alter behavior, and undermine anonymity. We obtained patient consent to video-record each trial appointment via a camera installed in the ceiling of the examination room. Using more than 20,000 minutes of recorded video, we are thus able to objectively capture a number of measures of both verbal and non-verbal patient engagement in a nonintrusive way while maintaining patient anonymity. Our engagement dataset covers 986 patients (493 in each trial arm), resulting in 3,629 observations at the patient-appointment level – we lost 36 observations due to technical errors in videotaping and 335 observations due to patients missing trial appointments or having one unscheduled visit instead of attending their scheduled second, third or fourth trial appointment.

As noted earlier, the stages for both appointment types mirrored one another, except that in SMAs each patient in the group was examined in turn by the doctor. In the introduction stage, the doctor and patient(s) exchanged greetings and seated themselves. During each patient’s examination, the doctor asked about the patient’s family history and whether family members had undergone glaucoma tests, inspected the patient’s eyes, and decided whether to continue or alter the patient’s treatment plan. In an SMA, patients were examined in an order that was randomly assigned during the first trial appointment. The assigned examination order was sustained in subsequent appointments unless there was a change in the group composition, due to postponement requests. If there was a change in the group composition, the study coordinators determined the patients’ examination order, with no input from the patients. After all examinations were completed, the appointment entered the post-examination interaction period. In a one-on-one appointment, the conversation between the patient and physician transitioned seamlessly to this phase, whereas in SMAs, the physician transitioned the conversation following the last patient examination by asking if anyone in the group had questions. In both arms, patients were free to ask questions during any stage of the appointment. As in regular practice, the doctors both asked and invited more questions if a patient’s condition appeared unstable.

Recall that in order to ensure identical scheduling across the trial arms, patients were scheduled to arrive in their assigned groups, for each appointment (see Figure 1). Since SMAs (which served 2 to 6 patients) lasted an average of 14.5 minutes longer than one-on-one appointments (which served a single patient), total speaking instances attributable to a patient are incomparable across the two arms. Patients in groups assigned to one-on-one appointments had no chance to speak up during the appointments of the other patients in their group, nor during changeovers. To overcome this challenge, we divide each patient’s total speaking instances by the duration of time spent serving that patient’s group. By analyzing speaking rates in this way (total speaking instances per minute), we normalize time discrepancies across the two arms, facilitating a valid comparison. By a similar procedure, we also compute the number of questions per minute, number of answers per minute, and number of non-question comments per minute contributed by each patient. Questions were identified in the verbatim transcripts as patient speaking instances that ended in a question mark. Answers were identified as patient speaking instances that followed immediately after a question posed by a doctor. Non-question comments were identified as patient speaking instances that did not follow a question posed by a doctor. Total speaking instances comprised the sum total of questions, answers, and non-question comments contributed by a patient.

We also captured demographic data for each patient – age, gender, urban/rural residence and education level, as well as medical information, such as glaucoma type and the presence of relevant comorbidities. Summary statistics for the demographic and medical information variables, which are provided in Supplementary Appendix Table A.3, indicate that random assignment resulted in balance across the treatment and control arms.

Guided by the prior literature on engagement – both in medical appointments and in more general settings – and our own direct observation in the field, we developed five measures of non-verbal engagement: attentiveness, positivity, head wobbling, eye contact, and leaning in. A transcriber viewed each appointment video from start to finish to rate each patient, during each stage of the appointment, on each of these five measures, using a 7-point Likert scale (see Figure 1). Likewise, the attentiveness and positivity of the doctors were also evaluated.

Following prior research, we defined *Attentiveness* as the extent to which the individual (patient or doctor) appeared to be energetic, dedicated, and focused (Seppälä et al. 2009, Bakker et al. 2008). *Positivity* measured the extent to which the individual seemed positive (i.e, satisfied, confident, hopeful) about the proceedings (Heikamp et al. 2014).

Head Wobbling, or ‘talai tallāṭṭam’ in Tamil, which involves nodding the head from side to side along the coronal plane, is a common gesture among the people of Southern India, including the Tamil Nadu region where we conduct our study. It can signal agreement, understanding, or appreciation, depending on the context (Brodsky 1987). Based on our direct observation of this gesture during trial appointments, we included Head Wobbling as a measure of the extent to which patients exhibited this gesture.

Eye Contact measured the extent of each patient’s eye contact with the doctor (and with fellow patients, if in an SMA). Greater eye contact and gaze are known to signal cooperative settings (Bavelas et al. 2002) and facilitate enjoyment, engagement, and learning (Kleinke 1986). *Leaning in* measured the extent to which a patient was leaning forward. Leaning in has been associated with paying attention and responding quickly in an interaction, whereas leaning out has been associated with boredom (D’Mello and Graesser 2009). Finally, we measured *End-of-Appointment Happiness* at each appointment, using a 6-point Likert scale, based on our observation that there was variation on this dimension across patients, as they left their appointments.

As a validity check for these subjective measures of non-verbal engagement, we also asked our transcribers to rate speech, measured as the extent to which a patient spoke with the doctor, (or with fellow patients, if in an SMA), on a 7-point Likert scale during each appointment stage. The correlation between patients’ total speech rating across all stages of an appointment and their total speaking instances extracted from the verbatim transcripts is 0.438 ($p < 0.000$), suggesting consistency across our subjective and objective verbal measures, and increasing confidence in our measures of non-verbal engagement.

Table 2 provides a model-free preview of our results – patients in SMAs exhibited significantly higher levels of verbal and non-verbal engagement on most measures than patients in one-on-one appointments.

Table 2 Summary Statistics

	(1)		(2)		(3)	
	Shared Medical Appointment (SMA)		One-on-One Appointment (1-1)		Differences	
	Mean	SD	Mean	SD	Difference	t-Value
Dependent Variables						
Total Speaking Instances Per Min	1.63	0.84	1.48	0.68	0.15***	(5.79)
Number of Questions Per Min	0.12	0.16	0.09	0.12	0.03***	(7.09)
Number of Non-question Comments Per Min	1.51	0.76	1.39	0.64	0.11***	(4.94)
Number of Answers Per Min	0.62	0.29	0.60	0.29	0.02**	(2.24)
Attentiveness	5.83	0.51	5.49	0.80	0.34***	(15.34)
Positivity	4.71	0.89	4.42	0.97	0.29***	(9.39)
Head Wobbling	3.67	0.81	0.06	0.39	3.61***	(170.97)
Eye Contact	6.00	0.08	5.98	0.28	0.02***	(2.95)
Leaning In	3.93	0.88	5.79	0.60	-1.86***	(-74.53)
End of Appointment Happiness	4.47	0.70	4.20	0.84	0.27***	(10.41)
Observations	1803		1826		3629	

*** p<0.01, ** p<0.05, * p<0.1.

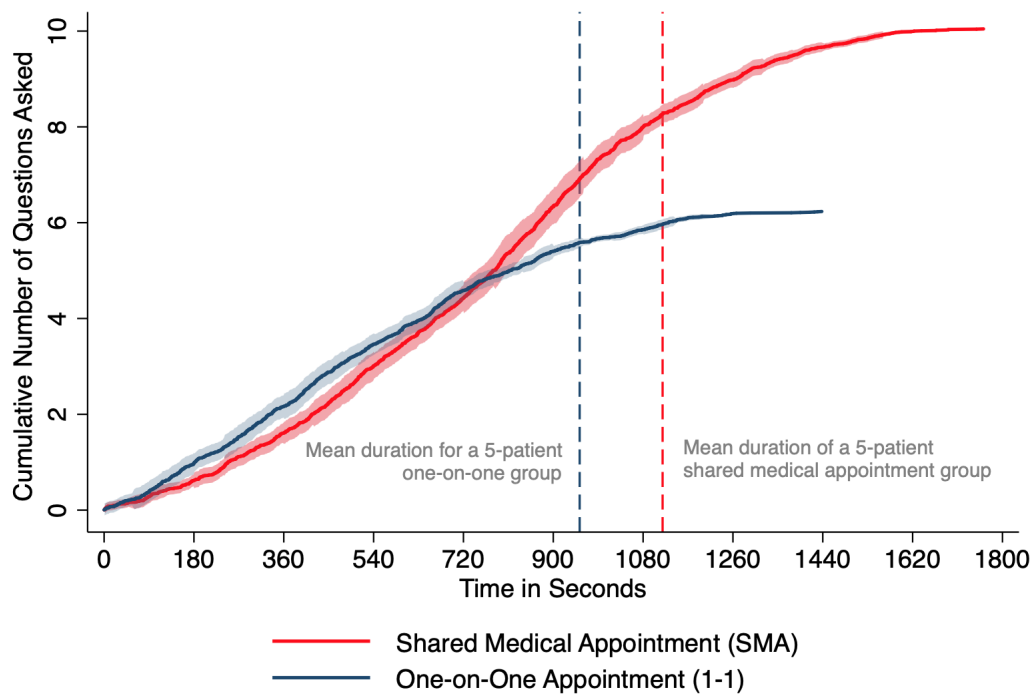
3. Empirical framework and results

We first compare how questions arise over time in SMAs and one-on-one appointments. Figure 2 plots the average cumulative number of questions initiated during each second, for five-patient groups randomly assigned to each trial arm. The blue curve highlights that for groups assigned to one-on-one appointments in which patients were seen serially, questions accumulated over time at a fairly constant rate in the first 720 seconds. This is intuitive, because the questions are arising from five independent appointments, one occurring after another. In contrast, the red curve highlights that questions in SMAs accumulated at an increasing average rate for the first 900 seconds. The confidence intervals for both curves become narrower over time, as the distributions of the durations of five-patient SMAs and of five-patient one-on-one groups have long right tails. Both curves eventually flatten, because there were very few groups in each arm with especially long total durations.

Figure 2 indicates that SMAs result in significantly more questions being asked than do one-on-one appointments, with the most dramatic difference occurring during the later stages, which during SMAs were dedicated to group interaction. Since appointments in both arms were terminated when all patient questions had been addressed, it is not surprising that SMAs in our trial lasted longer than one-on-one appointments serving equivalent numbers of patients. However, we note that since

SMA were more productive on a per-minute basis (Table 2), they would have nevertheless resulted in more engagement on all measures (patient speaking instances, questions asked, non-question comments, and answers) if they had been truncated to conclude after the mean duration for one-on-one appointments serving an equivalent number of patients. Indeed, Figure 2 visually demonstrates this case for question-asking behavior for five-patient SMAs. A supplementary analysis provides statistical tests for other countable measures of verbal engagement, including speaking instances, non-question comments, and answers provided (Supplementary Appendix Table A.4). We note that the results are substantively similar to the question-asking behavior documented in Figure 2, where shared delivery results in higher engagement levels.

Figure 2 Cumulative Number of Questions Asked by Groups of Five-Patients over Time



The figure above plots the average cumulative number of questions initiated during each second, for five-patient groups randomly assigned to either the shared medical appointments group or to the one-on-one appointments group. The blue curve represents the groups assigned to one-on-one appointments, whereas red curve represents the groups assigned to shared medical appointments. The shaded area around each curve depicts 95% confidence intervals. The blue vertical dashed line highlights the mean duration for a group of five consecutive one-on-one appointments, whereas the red vertical dashed line highlights mean duration for a five-patient shared medical appointment.

3.1. Effect of SMAs on verbal patient engagement

A common concern expressed by those who are apprehensive about SMAs is that patients may find SMAs to be less confidential, and may be less inclined to ask questions or make comments than in one-on-one appointments.

We first use the linear specification below to examine whether and to what extent patients' verbal engagement may differ between SMAs and one-on-one appointments.

$$\begin{aligned}
 Y_{it} = & \alpha_0 + \alpha_1 SMA_i + \alpha_2 Male_i + \alpha_3 Age_i + \alpha_4 Urban_i \\
 & + \alpha_5 Educ_i + \alpha_6 AppointmentNumber_t + \alpha_7 Doctor_t + v_{it}
 \end{aligned} \tag{1}$$

where Y_{it} represents four different measures of verbal engagement: total speaking instances per minute, number of questions per minute, number of non-question comments per minute, and number of answers per minute. *Male* is a dummy variable for biological sex. *Doctor* is a doctor indicator variable. *Age* is the age of patient i at the first trial appointment. *Urban* is an indicator for whether the patient resides in an urban (rather than rural) area. *Educ* represents a vector of dummy variables for five different education levels: illiterate, primary school education, secondary school education, undergraduate education, and postgraduate education. *AppointmentNumber_t* represents a vector of dummy variables that capture whether appointment t was patient i 's second, third, or fourth trial appointment, relative to a first-appointment baseline.¹ As in all primary analyses in this paper, we clustered standard errors at the patient level to account for potential within-patient serial correlation in errors across appointments and heteroskedastic errors across patients.

One might expect that patients whose turn to be examined by the doctor comes later in an SMA may speak less and have fewer unanswered questions, as their questions may have been already asked by patients who were examined earlier. During our trial, the sequence in which patients were seen in an SMA was randomly assigned during the first trial appointment. To investigate the

¹ Note that t could differ for the patients attending a particular appointment, because patients sometimes skipped a trial appointment.

contingent effects of patient sequence on the speaking behavior for patients randomly assigned to each trial arm, we use the modified linear specification below.

$$\begin{aligned}
 Y_{it} = & \delta_0 + \delta_1 SMAPatientSequence_{it} + \delta_2 Male_i + \delta_3 Age_i + \delta_4 Urban_i \\
 & + \delta_5 Educ_i + \delta_6 Doctor_t + \delta_7 AppointmentNumber_t + \varsigma_{it}
 \end{aligned}
 \tag{2}$$

where, as before, Y_{it} represents total speaking instances per minute, number of questions per minute, number of non-question comments per minute, or number of answers per minute.

Here, $SMAPatientSequence_{it}$ is a vector of five dummies that capture whether a patient in an SMA was examined first, second, third, fourth, fifth, or sixth by the doctor. The coefficients of these dummy variables represent the change in the average number of questions per minute asked by patients sequenced differently in SMAs relative to the base case of patients in one-on-one appointments.

Results are presented in Table 3, below. Column (1) indicates that patients randomly assigned to experience SMAs spoke 9.07% more times per minute than patients who experienced one-on-one appointments ($\alpha=0.145$, $p<0.01$). Similarly, Columns (3), (5), and (7) demonstrate that the number of questions asked per minute ($\alpha=0.033$, $p<0.01$) and the number of non-question comments per minute ($\alpha=0.113$, $p<0.01$) were significantly higher, and that the number of answers provided by patients per minute ($\alpha=0.020$, $p<0.10$) were also marginally higher among patients who experienced SMAs. Taken together, these results suggest that in aggregate, patients in shared medical appointments may be more verbally engaged than patients who experience one-on-one appointments.

Columns (2), (4), (6), and (8) explore whether the sequence in which patients are seen moderates the relationship between shared delivery and these measures of verbal engagement. Column (2) demonstrates that patients in SMAs, exhibited more total speaking instances per minute than patients who experienced one-on-one appointments when randomly assigned to one of the first four sequence positions. Relative to patients in one-on-one appointments, patients whose examinations were sequenced first ($\delta=0.180$, $p<0.01$), second ($\delta=0.140$, $p<0.01$), third ($\delta=0.236$, $p<0.01$),

Table 3 Impact of SMAs on Patients' Verbal Engagement

VARIABLES	(1) Total Speaking Instances Per Min	(2) Total Speaking Instances Per Min	(3) Number of Questions Per Min	(4) Number of Questions Per Min	(5) Number of Non-question Comments Per Min	(6) Number of Non-question Comments Per Min	(7) Number of Answers Per Min	(8) Number of Answers Per Min
Shared Medical Appointment (SMA)	0.145*** (0.031)		0.033*** (0.007)		0.113*** (0.028)		0.020* (0.011)	
First Patient		0.180*** (0.049)		0.025** (0.010)		0.156*** (0.045)		0.056*** (0.018)
Second Patient		0.140*** (0.048)		0.024*** (0.009)		0.117*** (0.044)		0.014 (0.016)
Third Patient		0.236*** (0.048)		0.055*** (0.011)		0.182*** (0.043)		0.049*** (0.018)
Fourth Patient		0.156*** (0.052)		0.046*** (0.010)		0.113** (0.047)		0.005 (0.017)
Fifth Patient		-0.024 (0.057)		0.013 (0.011)		-0.037 (0.051)		-0.046*** (0.017)
Sixth Patient		-0.267*** (0.064)		-0.026* (0.014)		-0.241*** (0.060)		-0.081*** (0.026)
Male	0.036 (0.033)	0.034 (0.033)	-0.008 (0.007)	-0.008 (0.007)	0.044 (0.029)	0.042 (0.029)	-0.005 (0.011)	-0.006 (0.011)
Age	-0.000 (0.002)	-0.000 (0.002)	0.001*** (0.000)	0.001*** (0.000)	-0.001 (0.001)	-0.001 (0.001)	-0.002*** (0.001)	-0.002*** (0.001)
Urban	0.054* (0.031)	0.055* (0.031)	0.022*** (0.006)	0.022*** (0.006)	0.034 (0.028)	0.034 (0.028)	0.004 (0.011)	0.004 (0.011)
Constant	1.599*** (0.112)	1.616*** (0.112)	0.057** (0.023)	0.057** (0.023)	1.545*** (0.101)	1.560*** (0.101)	0.663*** (0.045)	0.671*** (0.045)
Doctor Name FE	YES	YES	YES	YES	YES	YES	YES	YES
Education Level FE	YES	YES	YES	YES	YES	YES	YES	YES
Appointment Number FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,629	3,629	3,629	3,629	3,629	3,629	3,629	3,629
R-squared	0.055	0.063	0.043	0.050	0.052	0.059	0.042	0.050

Robust standard errors clustered at the patient level are in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

or fourth ($\delta=0.156$, $p<0.01$) exhibited a higher number of total speaking instances per minute than patients in one-on-one appointments. Patients sequenced fifth exhibited no significant difference in total speaking instances per minute ($\delta=-0.024$, $p=0.674$), whereas patients sequenced sixth in shared medical appointments engaged less ($\delta=-0.267$, $p<0.01$) than patients in one-on-one appointments.

This pattern was generally similar across all measures of verbal engagement. Question asking, sharing non-question comments, and providing answers to doctor-initiated queries were all elevated among patients who experienced SMAs, especially among those whose examinations were sequenced earlier in their appointments. This observed pattern is consistent with the idea that patients who, by virtue of their randomly-assigned examination sequence position are brought into the conversation sooner, may exhibit a higher degree of verbal engagement throughout the interaction. We observe

no systematic effect of sequence on patient satisfaction, learning, compliance or follow up behavior – which are presented in our related work (citation withheld for blind peer review).

3.2. Effect of SMAs on non-verbal patient engagement

To understand how SMAs impact non-verbal patient engagement, we analyze the patient examination stage for each patient, which resulted in 2-6 observations per SMA. Since the individual patient examination phase follows the same protocol in both trial arms, it is sensible to directly compare patient engagement during this phase, and any differences observed must be attributable to the presence or absence of other patients.

We use the linear specification below to estimate the impact of SMAs on each of the non-verbal patient engagement measures described above:

$$\begin{aligned}
 Y_{it} = & \gamma_0 + \gamma_1 SMA_i + \gamma_2 Male_i + \gamma_3 Age_i + \gamma_4 Urban_i + \gamma_5 Educ_i \\
 & + \gamma_6 TranscriberID_{it} + \gamma_7 AppointmentNumber_t + \gamma_8 Doctor_t + \eta_{it}
 \end{aligned}
 \tag{3}$$

where Y_{it} represents non-verbal patient engagement measures including attentiveness, positivity, head wobbling, eye contact, leaning in, and end-of-appointment happiness. For example, attentiveness represents the attentiveness score of patient i during his own examination stage by the doctor in appointment t . SMA is the treatment dummy and η is the error term.

Results are presented in Table 4 below. Column (1) indicates that the attentiveness for each patient was 5.69% higher among those randomly assigned to experience SMAs than for those who experienced one-on-one appointments ($\alpha=0.315$, $p<0.01$). Similarly, Columns (2), (3), (4), and (6) demonstrate that positivity ($\alpha=0.274$, $p<0.01$), head wobbling ($\alpha=3.650$, $p<0.01$), eye contact ($\alpha=0.018$, $p<0.10$), and end-of-appointment happiness ($\alpha=0.230$, $p<0.01$), were significantly higher among patients who experienced SMAs. Attending SMAs caused an increase in all but one of the non-verbal patient engagement variables we studied ($\alpha=-1.864$, $p<0.01$). Patients in SMAs were less likely to lean in during the proceedings. This observed pattern is consistent with the idea that a patient may wish to lean back more during their examination in a group setting, so as not to monopolize the conversation, and to appear more willing to share in the presence of others.

Table 4 Impact of SMAs on Patients' Non-verbal Engagement

Variables	(1) Attentiveness	(2) Positivity	(3) Head Wobbling	(4) Eye Contact	(5) Leaning in	(6) End of Appointment Happiness
Shared Medical Appointment (SMA)	0.315*** (0.024)	0.274*** (0.037)	3.650*** (0.021)	0.018*** (0.006)	-1.864*** (0.030)	0.230*** (0.030)
Male	0.034 (0.027)	0.007 (0.040)	0.018 (0.025)	-0.010 (0.007)	-0.067** (0.033)	0.026 (0.033)
Age	-0.002* (0.001)	-0.002 (0.002)	-0.002 (0.001)	-0.000 (0.000)	0.001 (0.002)	-0.001 (0.002)
Urban	0.080*** (0.026)	0.061 (0.039)	-0.016 (0.023)	0.009 (0.007)	0.010 (0.030)	0.102*** (0.032)
Primary School Education	0.149*** (0.046)	0.193*** (0.062)	0.023 (0.040)	0.000 (0.013)	0.052 (0.051)	0.125** (0.054)
Secondary School Education	0.198*** (0.068)	0.307*** (0.107)	0.024 (0.063)	0.014 (0.014)	0.104 (0.078)	0.202** (0.089)
Undergraduate Education	0.186*** (0.054)	0.324*** (0.078)	0.023 (0.050)	0.018 (0.014)	-0.010 (0.063)	0.225*** (0.065)
Postgraduate Education	0.194*** (0.058)	0.328*** (0.082)	0.067 (0.047)	0.001 (0.019)	0.009 (0.062)	0.246*** (0.069)
Constant	5.531*** (0.096)	4.209*** (0.151)	-0.149* (0.079)	5.986*** (0.029)	5.769*** (0.111)	4.059*** (0.124)
Appointment Number FE	YES	YES	YES	YES	YES	YES
Doctor Name FE	YES	YES	YES	YES	YES	YES
Transcriber ID FE	YES	YES	YES	YES	YES	YES
Observations	3,629	3,629	3,629	3,629	3,629	3,629
R-squared	0.124	0.053	0.909	0.007	0.617	0.142

Robust standard errors clustered at the patient level are in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

In a complementary analysis, we observe that the doctors in this trial were significantly less engaged and less positive in shared medical appointments, both at the start and end of the appointment (Supplementary Appendix Table A.6) and overall (Supplementary Appendix Table A.7). Indeed, this evidence suggests that patients in this trial exhibited increased engagement in the presence of physicians who, on average, were *less* engaged and *less* positive.

4. Discussion

Every provider must decide whether to deliver services to customers individually or in a group. This design choice is so fundamental that it often goes unquestioned. Some services – such as law and accounting – are reflexively practiced through one-on-one delivery models, whereas others – like education and entertainment – are habitually conducted through shared delivery models. Re-examining this fundamental aspect of service design may offer the potential for new service delivery innovation (Ramdas et al. 2012).

We conducted such an analysis in healthcare, a domain where one-on-one service delivery has, over time, been the near-universal norm. Although SMAs are known to improve efficiency and

patient outcomes (Edelman et al. 2015), they have exhibited slow adoption (Ramdas and Darzi 2017). Doctors and patients alike fear that patients will find SMAs unappealing, due to concerns that a lack of privacy may diminish engagement and hinder efficacy. However, results from our large-scale, multi-stage, randomized controlled trial indicate that, in the context of glaucoma follow up appointments, shared service delivery can significantly improve patients' verbal and non-verbal engagement.

On a minute-by-minute basis, we find that patients in SMAs ask 37.19% more questions, make 8.19% more non-question comments, and provide 3.62% more answers than patients in one-on-one appointments. Interestingly, in a complementary analysis presented in the supplementary appendix, we observe that doctors answer 37.57% more questions on a minute-by-minute basis, while making 10.98% more non-question comments and asking 3.40% fewer questions (Supplementary Appendix Table A.5). Taken together, this pattern of results suggests that SMAs may lead to more patient-directed healthcare interactions, which may, counterintuitively, be more suited to addressing patients' uncertainties, worries and doubts than traditional one-on-one care. Prior research has shown that when customers are anxious, reducing the barriers for them to ask questions can improve their confidence and satisfaction, inspiring greater trust (Shell and Buell 2020). In a similar light, future research can examine the extent to which SMAs may foster more trusting relationships among patients and providers, in both physical and virtual service delivery settings (Ramdas et al. 2020).

Our analysis also sheds light on the operational benefits that may arise from designing service models that enable customers to be more helpful in serving one another – leading to more efficacious service encounters in healthcare and beyond. During our trial, our physician partners observed patients in SMAs who became motivated to ask particular questions by hearing the questions and comments of other patients. Consistent with these efficacy benefits, we find that patients are observably more attentive and positive, make more direct eye contact, exhibit more outward signs of understanding, and emote greater levels of happiness during SMAs than in one-on-one appointments.

Crucially, evidence suggests that the improved engagement dynamics documented in this paper that arise from shared delivery may have more far-reaching implications for patients and providers alike. In related work that is based on the same randomized controlled trial, we find that SMAs increase patients' reported satisfaction levels with the appointment experience, and result in higher levels of patient knowledge as measured by tests about glaucoma subject matter (citation withheld for blind peer review). Perhaps most compellingly, in this related work we also find that patients' noncompliance to medications goes down by 39%. This pattern of results is generally consistent with a broad experimental literature on engagement in medical appointments, demonstrating that when patients have better experiences and are more engaged in their medical appointments, outcomes are likely to improve (Coulter and Ellins 2006, Griffin et al. 2004). Taken together, these results suggest that higher levels of patient engagement during SMAs may actually lead to sustained increases in patient engagement beyond the appointments themselves. To the extent that increased patient engagement inside SMAs can cause patients to become more engaged in their own care outside their appointments, SMAs may hold promise for improving long-term outcomes – an opportunity for future research.

Of course, shared delivery is not a panacea that can be applied to every operating scenario, and it is important to consider our results in context. Our results emanate from a single trial of patients undergoing treatment for glaucoma – a non-contagious condition for which the treatment protocol is highly routinized, and for which there is no stigma attached to being afflicted. SMAs would clearly be inappropriate for some conditions, where shared delivery would realize fewer efficiencies, or put patients in physical or psychological jeopardy. Future research should examine the boundary conditions of SMAs, validating factors that make shared delivery more or less appropriate. These factors can be examined from the perspective of patients, care providers, and payers. Relatedly, future research can delve into the cultural and contextual considerations that facilitate or hinder the efficacy of shared delivery. For example, SMAs may be more efficacious in collectivist cultures, and less efficacious in individualistic cultures.

Our findings that shared service delivery can lead to increased engagement in medical appointments – a context where doctor-patient confidentiality is highly prized – suggest that it may be worth considering their use in other service settings.

The exploration of shared service delivery models in operations is relatively nascent. Although there has been recent interest in modelling shared delivery in more transactional services such as shared rides (Lobel and Martin 2020) or bus scheduling (Bertsimas et al. 2019), future streams of research could investigate how they might best be leveraged to optimize customer experiences and operating efficiency in customer-intensive, high-value services. Research could identify which other consultative service settings, where customers have the potential to benefit from the perspectives and experiences of one another, could be improved by the incorporation of shared service delivery – leading to more satisfying and engaging interactions, and perhaps, better long-term outcomes as well.

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Supplementary Appendix

A.1 Distribution of Number of Patients in an SMA

Number of Patients	Percentage of SMAs
2	0.74%
3	17.44%
4	28.75%
5	43.00%
6	10.07%

A.2 Sample Selection Criteria

Inclusion Criteria
1. The patient must be a primary glaucoma patient
2. The patient must not have had more than one surgery in one eye in the past
3. The patient must not have undergone a tube/ shunt surgery
4. The patient must not be monocular
5. The patient should not require surgical intervention in the near future
6. The patient must not wish to interact with a specific doctor
7. It is believed that the patient will interact effectively in a group setting
8. The patient should not be a part of any other existing trial
9. The patient should not have any vision threatening condition other than glaucoma

Our study inclusion criteria were developed in collaboration with Aravind. We note that although criterion 7 was specified prior to the trial to exclude patients for whom it was believed that they would not interact effectively in a group setting, no patient was excluded for this reason.

A.3 Balance Statistics

	(1)		(2)		(3)	
	Shared Medical Appointment (SMA)		One-on-One Appointment (1-1)		Differences	
	Mean	SD	Mean	SD	Difference	t-Value
Demographic Variables						
Age	61.95	9.16	62.08	9.54	-0.14	(-0.23)
Proportion of Male Patients	0.58	0.49	0.63	0.48	-0.05	(-1.56)
Urban	0.62	0.49	0.61	0.49	0.01	(0.33)
Education	2.55	1.17	2.58	1.24	-0.02	(-0.29)
Medical Variables:						
Proportion of Glaucoma Types						
Primary Open Angle Glaucoma (POAG)	0.73	0.44	0.75	0.43	-0.01	(-0.51)
Primary Angle Closure Disease (PACD)	0.23	0.42	0.22	0.41	0.01	(0.23)
Ocular Hypertension (OHT)	0.01	0.09	0.01	0.10	-0.00	(-0.33)
Pseudoexfoliation Glaucoma (PXF Glaucoma)	0.03	0.18	0.02	0.14	0.01	(1.19)
Proportion of Comorbidities						
Diabetes	0.37	0.48	0.38	0.49	-0.01	(-0.39)
Hypertension	0.35	0.48	0.38	0.48	-0.02	(-0.66)
Cardiac Disease	0.04	0.20	0.03	0.18	0.01	(0.68)
Asthma/Chronic Obstructive Pulmonary Disease (COPD)	0.02	0.15	0.02	0.13	0.01	(0.69)
Other Chronic Diseases	0.00	0.06	0.01	0.10	-0.01	(-1.14)
Observations	493		493		986	

There were no significant differences between the trial groups for any characteristic. The education variable is scaled as: Illiterate (1); Primary School Education (2); Secondary School Education (3); Undergraduate Education (4); Postgraduate Education (5). *** p<0.01, ** p<0.05, * p<0.1.

A.4 Summary Statistics

	(1)		(2)		(3)	
	Shared Medical Appointment (SMA)		One-on-One Appointment (1-1)		Differences	
	Mean	SD	Mean	SD	Difference	t-Value
Dependent Variables						
Cumulative Number of Speaking Instances	106.94	26.76	99.99	25.35	6.95***	(2.54)
Cumulative Number of Questions	7.07	4.88	5.70	3.30	1.37***	(3.12)
Cumulative Number of Non-question Comments	58.08	19.62	54.27	18.80	3.80**	(1.88)
Cumulative Number of Answers	42.16	9.82	40.18	10.89	1.97**	(1.81)
Observations	175		188		363	

Five-patient SMAs resulted in more engagement on all measures – cumulative number of speaking instances, cumulative number of questions, cumulative number of non-question comments and cumulative number of answers – compared to the group of five consecutive one-on-one appointments, when they had been truncated to conclude at the mean duration of five consecutive one-on-one appointments – 952.89 seconds. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Below, we present analyses for doctors' verbal engagement during an appointment.

A.5 Impact of SMAs on Doctors' Verbal Engagement

Variables	(1)	(2)	(3)	(4)
	Total Speaking Instances Per Min	Number of Questions Per Min	Number of Non-question Comments Per Min	Number of Answers Per Min
Shared Medical Appointment (SMA)	0.307*** (0.102)	-0.103** (0.048)	0.441*** (0.083)	0.124*** (0.019)
Constant	8.395*** (0.146)	2.967*** (0.068)	5.571*** (0.119)	0.462*** (0.028)
Appointment Number FE	YES	YES	YES	YES
Doctor Name FE	YES	YES	YES	YES
Observations	809	809	809	809
R-squared	0.217	0.054	0.272	0.112

We note that these results are based on data from the two ophthalmologists who administered this trial, and hence we do not present these as primary analyses in the manuscript. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Doctors answer more questions on a minute-by-minute basis, while making more non-question comments and asking fewer questions in shared medical appointments than in one-on-one appointments.

Below, we present analyses for doctors' non-verbal engagement during different stages of an appointment.

Doctors are significantly less attentive and less positive in shared medical appointments both at the start and at the end of the appointment, than in one-on-one appointments.

A.6 Impact of SMAs on Doctors' Non-verbal Engagement during Different Stages of an Appointment

Variables	(1) Attentiveness in Introduction	(2) Positivity in Introduction	(3) Attentiveness in Patient Examination	(4) Positivity in Patient Examination	(5) Attentiveness in Q &A	(6) Positivity in Q &A
Shared Medical Appointment (SMA)	-1.311*** (0.053)	-0.617*** (0.070)	0.005 (0.005)	0.243*** (0.029)	-0.868*** (0.050)	-0.427*** (0.066)
Constant	5.077*** (0.055)	4.329*** (0.072)	5.988*** (0.008)	5.409*** (0.035)	5.990*** (0.052)	5.317*** (0.069)
Appointment Number FE	YES	YES	YES	YES	YES	YES
Doctor Name FE	YES	YES	YES	YES	YES	YES
Transcriber Name FE	YES	YES	YES	YES	YES	YES
Observations	2,230	2,230	3,629	3,629	2,228	2,228
R-squared	0.094	0.045	0.904	0.005	0.612	0.121

We note that these results are based on data from the two ophthalmologists who administered this trial, and hence we do not present these as primary analyses in the manuscript. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Below, we present analyses for doctors' positivity and engagement across the stages of their appointments.

A.7 Impact of SMAs on Doctors' Non-verbal Engagement

Variables	(1) Attentiveness across Stages	(2) Positivity across Stages	(3) Attentiveness across Stages	(4) Positivity across Stages
Shared Medical Appointment (SMA)	-0.725*** (0.051)	-0.263*** (0.054)	-0.335*** (0.023)	-0.004 (0.035)
Constant	5.683*** (0.032)	4.947*** (0.047)	5.754*** (0.022)	5.105*** (0.038)
Appointment Number FE	YES	YES	YES	YES
Doctor Name FE	YES	YES	YES	YES
Transcriber Name FE	YES	YES	YES	YES
Observations	6,688	6,688	8,087	8,087
R-squared	0.129	0.065	0.062	0.067

The examination stage was aggregated across patients in an SMA in Columns (1) and (2). This stage was considered at the disaggregate level in Columns (3) and (4). We note that these results are based on data from the two ophthalmologists who administered this trial, and hence we do not present these as primary analyses in the manuscript. Robust standard errors, clustered at the appointment level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

When the examination stage is considered at the disaggregate level (Columns (3) and (4)), doctors are significantly less engaged across all stages of the appointment (Column (3)) and there is no significant difference in doctors' positivity (Column (4)).