

# Pre-Analysis Plan

Effects of Physical Characteristics of Meeting Spaces on Discussion Activity, Psychological States, and Autonomic Nervous System Responses

## 1. Treatment Conditions (Six Conditions, Multi-Valued Treatment)

Six spatial conditions are treated as mutually exclusive treatment groups in a multi-valued treatment design. Panel (full panel) serves as the reference condition, and each of the remaining five conditions is treated as an independent comparison condition.

Code	Condition	Acoustic Privacy	Visual Privacy	Physical Implementation
P (ref.)	Panel	High (sound-isolated)	High	Full panel
FOG	Frosted Glass	High (sound-isolated)	Medium	Frosted glass (semi-transparent)
G	Glass	High (sound-isolated)	Low	Glass partition
OP	Open	Low (not sound-isolated)	None	Open
F	Frame	Low (not sound-isolated)	Medium	Frame only
R	Louver	Low (not sound-isolated)	High	Louver

### 1-1. Estimands

Primary estimand	The difference between Panel (reference) and each of the other five conditions (condition-specific treatment effects; five ATEs)
Secondary estimand	Aggregate comparisons after reclassifying conditions by acoustic privacy (present/absent) and visual privacy (high/medium/low) (mechanism exploration)

### 1-2. Identification Strategy

The primary analysis treats the six conditions as individual treatment groups and estimates each condition's difference from the reference (Panel). Because the six conditions are not an idealized factorial experiment and differences across physical implementations are also mixed in, the study does not claim that any single pairwise comparison isolates “the effect of acoustic privacy alone” or “the effect of visual privacy alone.” As a secondary analysis, conditions are reclassified by acoustic and visual privacy level and compared in aggregate on an exploratory basis.

## 2. Randomization and Assignment Schedule

**Unit of Randomization** : Meeting group × week (meeting group-week)

- Each meeting group is assigned a pre-specified order of the six conditions prior to the study (the order differs across groups)

- Conditions are fixed at the group-week level
- Groups enter the study on different dates under a phased rollout.
- After a group enters the study, conditions are updated weekly, typically on Mondays
- For groups that meet more often than once per week (daily meeting groups), the analytic observation unit is likewise standardized to one pre-specified representative meeting per treatment week, to align observation with the weekly treatment assignment
- If a group does not complete a full rotation through all six conditions, the observations obtained are still included in the analysis
- Instances meeting the pre-specified operational definitions of report-only meeting or short meeting are excluded from the analytic sample (definitions in Section 4-3)

### 3. Target Groups

The target population consists of recurring meeting groups within the firm (Komany Corporation), with up to six groups participating concurrently and up to eight candidate groups (joining sequentially across Phases I–IV). Both weekly and daily meeting groups are included; no new groups are added for research purposes during the study period.

#### Group-Change Rules

- If a majority of a group's members change due to personnel reassignment, the group is re-labeled as a new group
- If fewer than a majority of members change, the group continues to be treated as the same group
- Replacement of departing members is permitted, but only for pre-defined, naturally occurring changes

#### Target Group List as of Study Launch

*The four Phase I groups have confirmed start dates. Phase II–IV groups depend on equipment readiness and personnel changes and remain unconfirmed as of this PAP submission. “Phase count” denotes how many times a given group repeats the 6-week cycle needed to rotate once through all six conditions. “Total meetings” is the total number of raw meeting occurrences (phase count × meetings per week × 6 weeks), including all 5 weekly occurrences for daily groups; this differs from the primary analysis observation unit (one representative meeting per treatment week) defined in Section 6-1 onward.*

Group ID	Size	Phase Count	Meetings/Week	Total Meetings	Person-Instances
1	4	4	5	120	480
2	4	4	1	24	96
3	3	4	1	24	72
4	3	4	1	24	72
5	5	3	5	90	450
6	5–6	3	5	90	450–540
7	5	2	1	12	60
8	4	1	1	6	24
<b>Total</b>				<b>390</b>	<b>1,704–1,794</b>

*Note: Group 6's size ranges from 5–6 members, so its person-instances figure is likewise reported as a range.*

## 4. Experimental Implementation Conditions

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### 4-1. Eligible Meetings for the Primary Analysis (In-Person Participation Criteria)

- At least 3 participants attend in person
- In-person participation rate (in-person / total participants) of at least 70%
- Attendance rate (actual attendees / group roster size) of at least 80%

### 4-2. Treatment of Hybrid Meetings: Operational Definition

Hybrid meetings (meetings routinely operated with remote participants) are excluded from the primary analysis. Rationale: although treatment is the “spatial condition,” remote participation alters the acoustic environment and conversational structure, confounding it with the treatment effect; heart-rate data can only be obtained from in-person participants.

### 4-3. Exclusion Criteria: Pre-Specified Operational Definitions

To avoid post hoc discretion in exclusion decisions, the following criteria are defined quantitatively in advance.

Exclusion Category	Operational Definition (Pre-Specified)
Short meeting	Meeting duration under 10 minutes, determined mechanically from Microsoft Teams meeting records (start/end timestamps).
Report-only meeting	A meeting in which one-way reporting or announcements without Q&A or discussion account for at least 80% of agenda time, determined from a post-meeting questionnaire (completed by the chair or a participant).
Participant-count shortfall	Fewer than 3 in-person participants, or failing the in-person participation rate / attendance rate criteria in Section 4-1.
Substantial format deviation	An instance that differs substantially from the group's normal meeting format (e.g., an ad hoc meeting substituted in, or overlap with a company-wide event).
Condition not applied	An instance in which the scheduled change in spatial condition was not implemented.
Missing data	An instance with missing primary outcome data due to sensor malfunction, communication failure, or failed transcription.

### 4-4. Observation Unit and Representative-Meeting Selection Rule for Daily Meetings

For meeting groups that hold meetings more often than once per week (daily meeting groups), the analytic observation unit is, likewise, one pre-specified representative meeting per treatment week, aligning observation with the weekly treatment assignment. The representative meeting is defined by fixing a day of the week in advance for each treatment week (e.g., the group's regular daily meeting held every Tuesday is designated the representative meeting). If the designated day's meeting meets an exclusion criterion in Section 4-3, that treatment week is treated as missing; no substitution to a different day of the week is made, in order to avoid post hoc selection.

## 5. Planned Sample Size

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Definition of observation unit: the primary analysis sample is defined at the meeting-session level. One session corresponds to one representative meeting for a given meeting group in a given treatment week (for weekly groups, that week's regular meeting; for daily groups, the representative meeting defined in Section 4-4). Within each session, physiological outcomes are further observed as a participant-by-minute time series.

The “total meetings” figure in the Section 3 group table (390) is the total number of raw meeting occurrences, including all weekly occurrences for daily groups; it differs from the primary analysis observation unit (one representative meeting per treatment week). The relationship between the two is shown below.

Category	Total Meetings (Reference)	Primary Analysis Sessions (Planned)
Weekly meeting groups (IDs 2, 3, 4, 7, 8)	90	90 sessions
Daily meeting groups (IDs 1, 5, 6; aggregated to one representative session per treatment week)	300	60 sessions
<b>Total</b>	<b>390</b>	<b>150 sessions</b>

The total meeting count (390) is the number of meetings each group actually holds — for daily groups, accumulated at 5 (or biweekly 5) occurrences per week across the relevant phase duration. The primary analysis session count (150), by contrast, is the number of analytic units in the two-way fixed-effects model, obtained by selecting one representative meeting per treatment week. The two figures are reported separately to avoid conflating the scale of raw data collection with the primary analysis sample size.

## 6. Estimation Methods and Analysis Plan

### 6-1. Baseline Estimation Method (Two-Way Fixed Effects)

$Y_{igw} = \alpha + \sum_k \beta_k \cdot Condition_{kw} + \gamma_i + \delta_w + X_{igw} \cdot \varphi + \varepsilon_{igw}$		
Symbol	Definition	Notes
$Condition_{kw}$	Dummy variable for spatial condition k	$k \in \{FOG, G, OP, F, R\}$ ; reference = P (Panel)
$\beta_k$	Treatment effect of condition k	Difference from condition P; the main parameter of interest
$\gamma_i / \delta_w$	Individual / week fixed effects	Removes individual differences and day-of-week/week variation
$\varepsilon_{igw}$	Error term	Standard errors clustered at the group (g) level

Unit of analysis: heart-rate outcomes are estimated at the individual × meeting (weekly representative meeting) level; speech outcomes at the meeting (weekly representative meeting) level. The secondary estimand is estimated analogously using aggregated dummies reclassified by acoustic and visual privacy.

### 6-2. Time-Series Estimation (5-Minute Intervals During the Meeting, 10-Minute Intervals After)

The unit of observation is the heart-rate interval (RRI). Within 5-minute bins during the meeting and 10-minute bins afterward, mean differences from condition P are compared over time, and a fixed-effects model with treatment × time-bin interactions estimates the timing of effect onset and persistence.

$$Y_{igtw} = \alpha + \sum_k \sum_\tau \beta_{k\tau} \cdot (Condition_{kw} \times TimeFrame_\tau) + \sum_k \sum_\tau \theta_{k\tau} \cdot (Condition_{kw} \times PostFlag_\tau) + \gamma_i + \delta_w + \lambda_t + X_{igtw} \cdot \varphi + \varepsilon_{igtw}$$

- Instances in which the meeting is unusually short are excluded
- When full-day wearable data is used, the rule delimiting in-meeting and post-meeting windows is specified in advance
- For daily meeting groups, only the weekly representative meeting (Section 4-4) is used in the time-series analysis

### 6-3. Multiple Testing Adjustment

- The Benjamini-Hochberg procedure (FDR control) is applied across all primary indicators
- A pre-specified priority order (1. RMSSD time series, 2. LF/HF ratio time series, 3. speech volume) identifies the most important tests
- Both unadjusted and adjusted p-values are reported

### 6-4. Sensitivity Analyses

- Comparison between excluding absent sessions and using multiple imputation
- Robustness check excluding hybrid meetings, then adding back meetings with exceptional remote participation
- Robustness check using alternative in-person participation rate thresholds (70% / 80%)
- Robustness check using alternative NLP methods for sentiment polarity (dictionary-based vs. machine-learning models)
- Consistency check between RMSSD and LF/HF ratio results
- Robustness check using alternative time-series window widths (in-meeting: 2, 5, 10 minutes; post-meeting: 5, 10, 20 minutes)
- Consistency check between the secondary analysis (acoustic/visual privacy reclassification) and the primary analysis

### 6-5. Control Variables

Category	Variable	Operational Definition	Source
Meeting attributes	Meeting type; group size; in-person/remote participant counts	Approx. 3–6 members per group	Experimental record
Participant characteristics	Position, age, gender	Managerial/non-managerial status, average age, gender composition	In-house information (ID-coded)
Temporal factors	Day of week, time of day, month, previous week's condition	Monday–Friday; morning/afternoon/evening; month dummies	Experimental record
Environmental factors	Room temperature, humidity, CO <sub>2</sub>	Mean values during the meeting session	Environmental sensor (automatic)
Health status	WHO-5, physical condition, sleep	5-item Likert scale; self-reported condition; prior night's sleep duration	Questionnaire

Category	Variable	Operational Definition	Source
Organizational factors	Post-reassignment / group-restructuring dummy	Applies when the group-change rule in Section 3 is triggered	Experimental record