

# Supplementary Material

## Exploring defining single value indices - SPI

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### 1. Exploring defining single value indices - SPI

This notebook contains several explorations and developments leading to the SPI framework.

### 2. Setup

#### 2.1. Import Libraries

```
/Users/mitch/Library/CloudStorage/OneDrive-UniversityCollegeLondon/_Fellowship/Papers - Drafts/J2401_...
warnings.warn('The global conversion available with activate() '
/Users/mitch/Library/CloudStorage/OneDrive-UniversityCollegeLondon/_Fellowship/Papers - Drafts/J2401_...
warnings.warn('The global conversion available with activate() ')
```

#### 2.2. Load Data

In addition to loading the latest version of the ISD, we also exclude a few samples that were identified as survey outliers. Most notably, this includes the samples at RegentsParkFields which were impacted by helicopter flyovers.

	LocationID	SessionID	GroupID	RecordID	start_time	end_time	latit
0	CarloV	CarloV2	2CV12	1434	2019-05-16 18:46:00	2019-05-16 18:56:00	37.1
1	CarloV	CarloV2	2CV12	1435	2019-05-16 18:46:00	2019-05-16 18:56:00	37.1
2	CarloV	CarloV2	2CV13	1430	2019-05-16 19:02:00	2019-05-16 19:12:00	37.1
3	CarloV	CarloV2	2CV13	1431	2019-05-16 19:02:00	2019-05-16 19:12:00	37.1
4	CarloV	CarloV2	2CV13	1432	2019-05-16 19:02:00	2019-05-16 19:12:00	37.1
...	...	...	...	...	...	...	...
1693	Noorderplantsoen	Noorderplantsoen1	NP161	61	2020-03-11 12:42:00	2020-03-11 12:55:00	NaN
1694	Noorderplantsoen	Noorderplantsoen1	NP162	63	2020-03-11 12:39:00	2020-03-11 13:00:00	NaN
1695	Noorderplantsoen	Noorderplantsoen1	NP162	62	2020-03-11 12:54:00	2020-03-11 12:58:00	NaN
1696	Noorderplantsoen	Noorderplantsoen1	NP162	64	2020-03-11 12:56:00	2020-03-11 12:59:00	NaN
1697	Noorderplantsoen	Noorderplantsoen1	NP163	70	2020-03-11 23:08:00	2020-03-11 23:18:00	NaN

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### 2.2.1. ISOCoordinate calculation according to Aletta et. al. (2024)

To move the 8-item PAQ responses into the 2-dimensional circumplex space, we use the projection method first presented in ISO 12913-3:2018. This projection method and its associated formulae were recently updated further in ? to include a correction for the language in which the survey was conducted. The formulae are as follows:

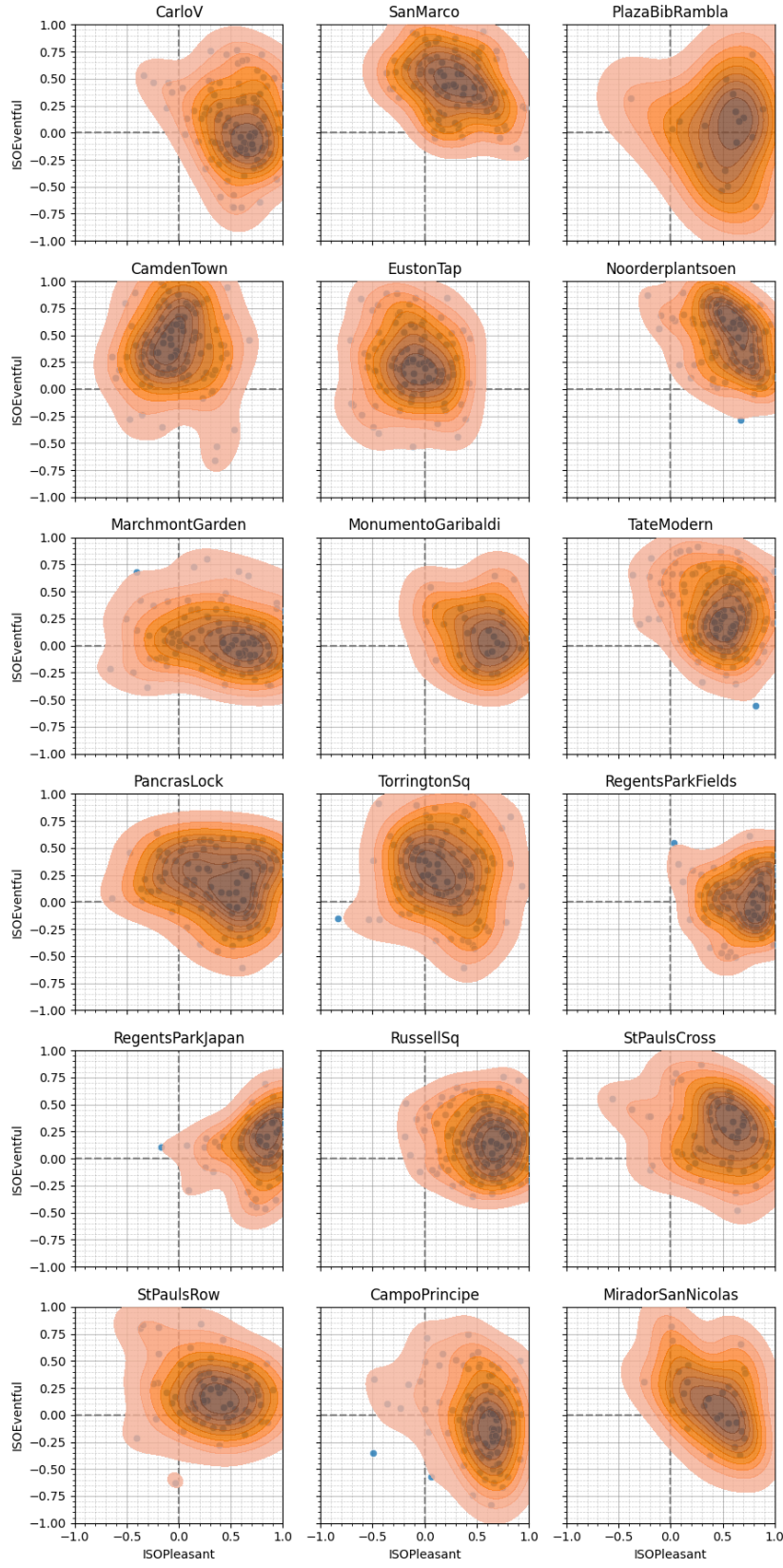
$$P_{ISO} = \frac{1}{\lambda_{pl}} \sum_{i=1}^8 \cos \theta_i \cdot \sigma_i E_{ISO} = \frac{1}{\lambda_{pl}} \sum_{i=1}^8 \sin \theta_i \cdot \sigma_i$$

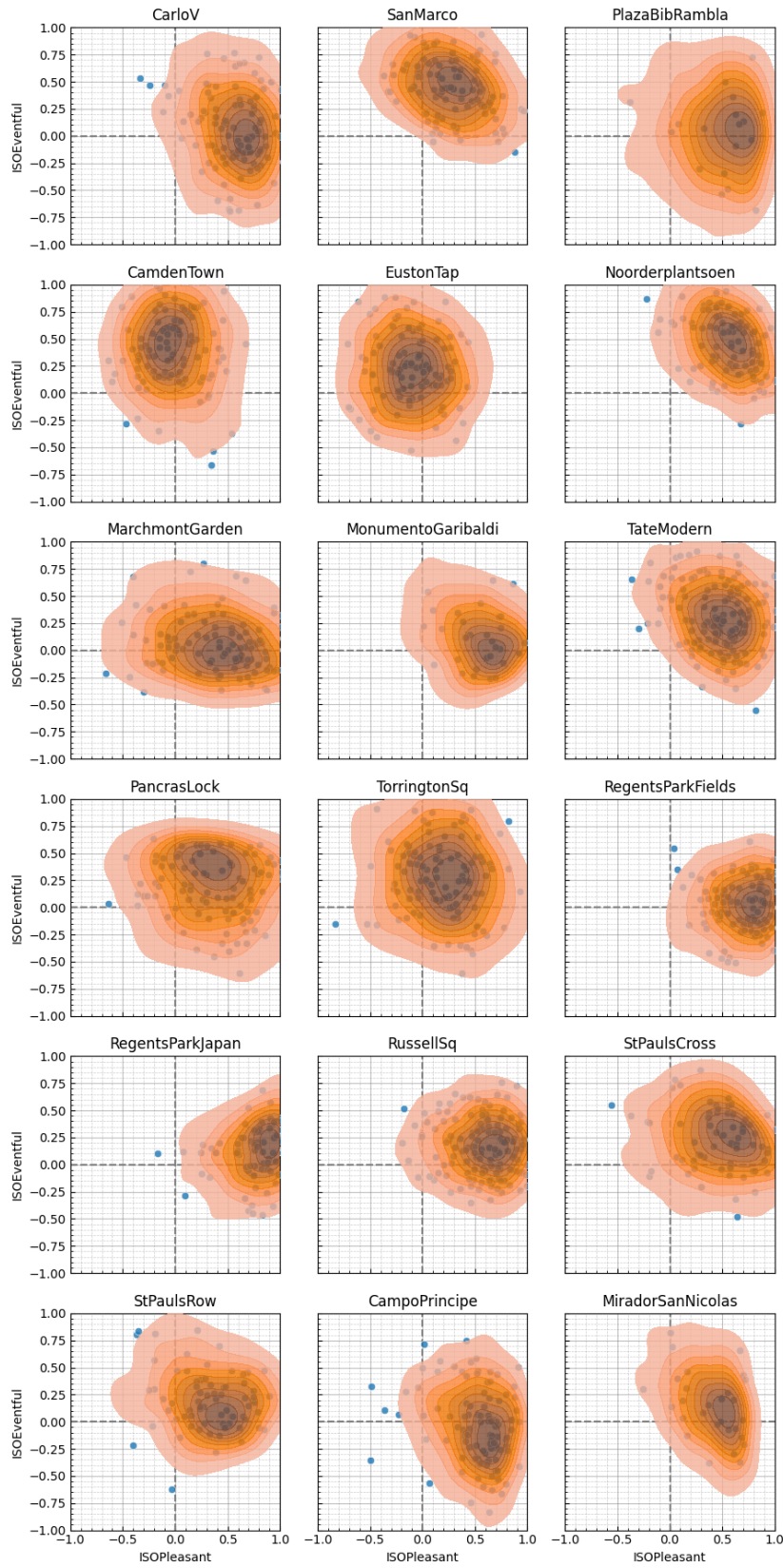
where \$PAQ\_i\$ is the response to the (i)th item of the PAQ. The resulting (x) and (y) values are then used to calculate the polar angle ( ) and the radial distance (r) as follows:

```
{'eng': (0, 46, 94, 138, 177, 241, 275, 340),
'arb': (0, 36, 45, 135, 167, 201, 242, 308),
'cmn': (0, 18, 38, 154, 171, 196, 217, 318),
'hrv': (0, 84, 93, 160, 173, 243, 273, 354),
'nld': (0, 43, 111, 125, 174, 257, 307, 341),
'deu': (0, 64, 97, 132, 182, 254, 282, 336),
'ell': (0, 72, 86, 133, 161, 233, 267, 328),
'ind': (0, 53, 104, 123, 139, 202, 284, 308),
'ita': (0, 57, 104, 143, 170, 274, 285, 336),
'spa': (0, 41, 103, 147, 174, 238, 279, 332),
'swe': (0, 66, 87, 146, 175, 249, 275, 335),
'tur': (0, 55, 97, 106, 157, 254, 289, 313)}
```

Table 2: Language-specific angles for projection into the ISO 12913-3:2018 circumplex space.

	PAQ1	PAQ2	PAQ3	PAQ4	PAQ5	PAQ6	PAQ7	PAQ8
eng	0	46	94	138	177	241	275	340
arb	0	36	45	135	167	201	242	308
cmn	0	18	38	154	171	196	217	318
hrv	0	84	93	160	173	243	273	354
nld	0	43	111	125	174	257	307	341
deu	0	64	97	132	182	254	282	336
ell	0	72	86	133	161	233	267	328
ind	0	53	104	123	139	202	284	308
ita	0	57	104	143	170	274	285	336
spa	0	41	103	147	174	238	279	332
swe	0	66	87	146	175	249	275	335
tur	0	55	97	106	157	254	289	313





### 2.3. The Soundscape Perception Index (SPI)

The SPI works by assessing the assessed (or calculated) distribution of soundscape responses against a target distribution. This target distribution represents the goal for the soundscape design. Since we consider a location's soundscape perception to be the collective perception of its users, it is crucial that the target includes both the central tendency and the distribution.

#### 2.3.1. Note: Distributions in the circumplex

We should begin by discussing how soundscape circumplex distributions are defined. The circumplex is defined by two axes:  $P_{ISO}$  and  $E_{ISO}$  which are limited to the range  $[-1, 1]$ . Typically the distribution of collective perception of a soundscape is also not symmetrical, therefore making it a skewed distribution. A soundscape distribution is thus a two-dimensional truncated skew-normal distribution.

The skew-normal distribution is defined by three parameters: location, scale and shape. The location parameter defines the centre of the distribution, the scale parameter defines the spread of the distribution, and the shape parameter defines the skew of the distribution. The skew-normal distribution is defined as:

$$f(x; a, \omega, \alpha) = \frac{2}{\omega} \phi\left(\frac{x-a}{\omega}\right) \Phi\left(\alpha \frac{x-a}{\omega}\right)$$

where  $\phi$  and  $\Phi$  are the standard normal probability density function and cumulative distribution function respectively. The skew-normal distribution is thus a generalisation of the normal distribution, with the shape parameter  $\alpha$  defining the skew. A positive shape parameter results in a right-skewed distribution, and a negative shape parameter results in a left-skewed distribution.

Truncated skew-normal distribution: <https://www.tandfonline-com.libproxy.ucl.ac.uk/doi/epdf/10.1080/03610910902936>

To generate the truncated skew-normal distribution, we use rejection sampling. This is a method of generating a distribution by sampling from a simpler distribution and rejecting samples that do not fit the target distribution. In this case, we sample from a skew-normal distribution (`scipy.stats.skewnorm`) and reject samples that are outside of the range  $[-1, 1]$ .

*2.3.1.1. Example - Calculating the moments of location's distribution and generating the equivalent distribution using rejection sampling.*

Fitted from data. n = 96

Direct Parameters:

xi: [[0.06 0.597]]

omega: [[ 0.15 -0.058]

[-0.058 0.093]]

alpha: [ 0.868 -0.561]

Centred Parameters:

mean: [[0.281 0.447]]

sigma: [[ 0.101 -0.025]

[-0.025 0.07 ]]

skew: [ 0.145 -0.078]

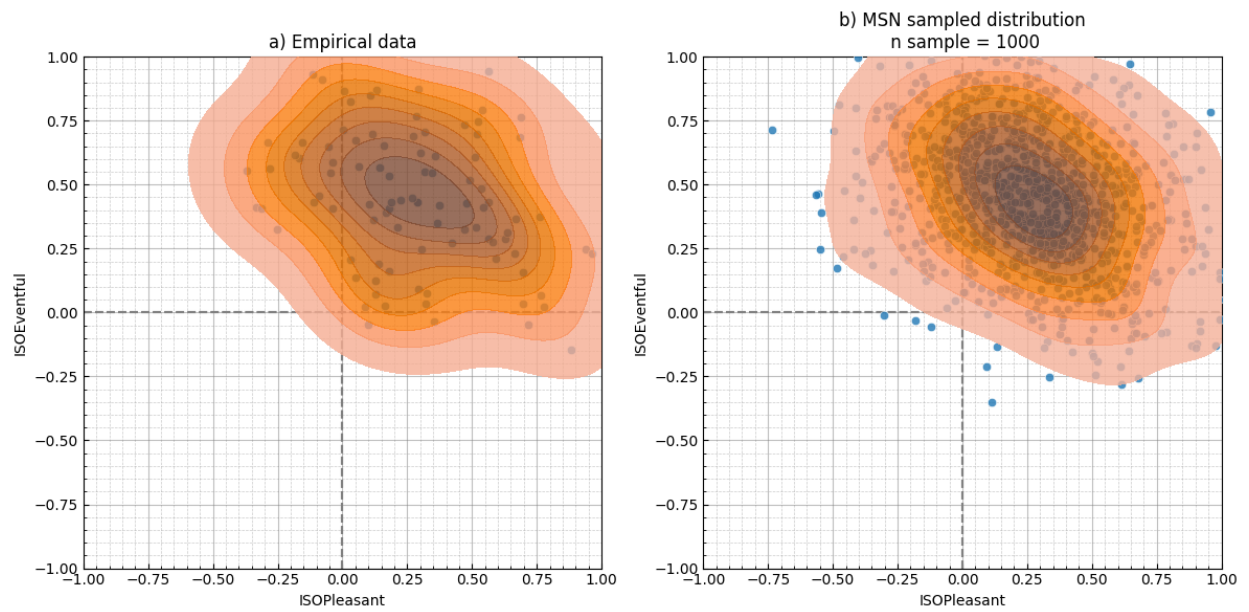
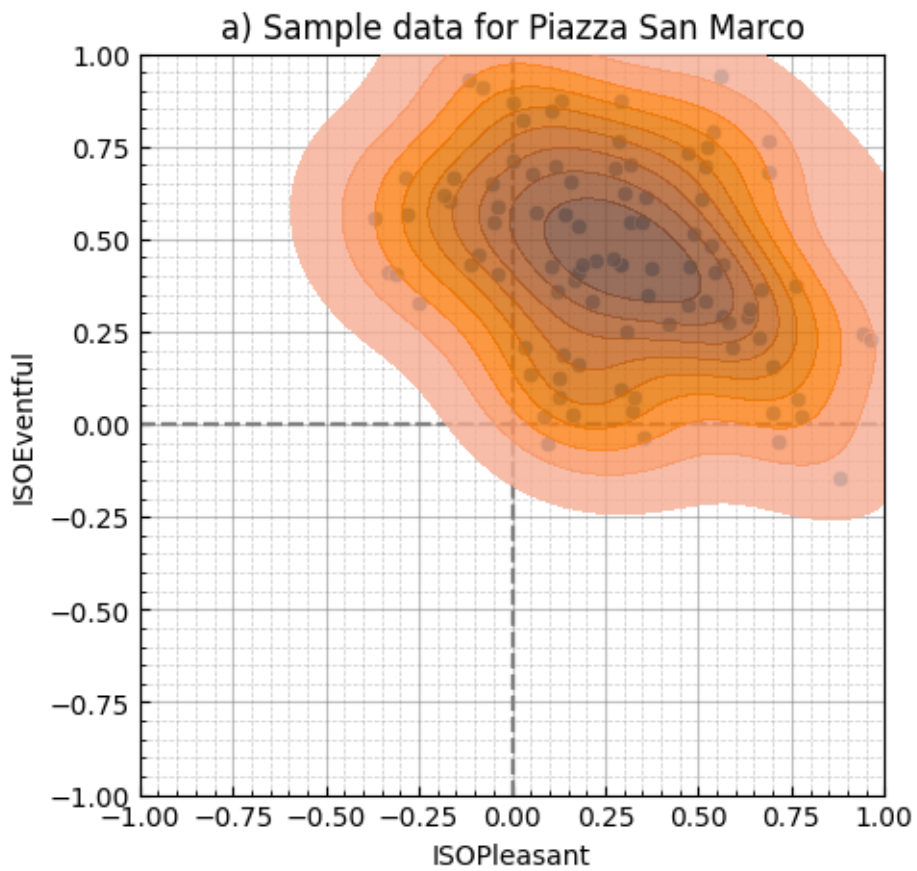


Figure 1: Example of fitting and sampling from a multivariate skew-normal distribution for data from the Piazza San Marco location.





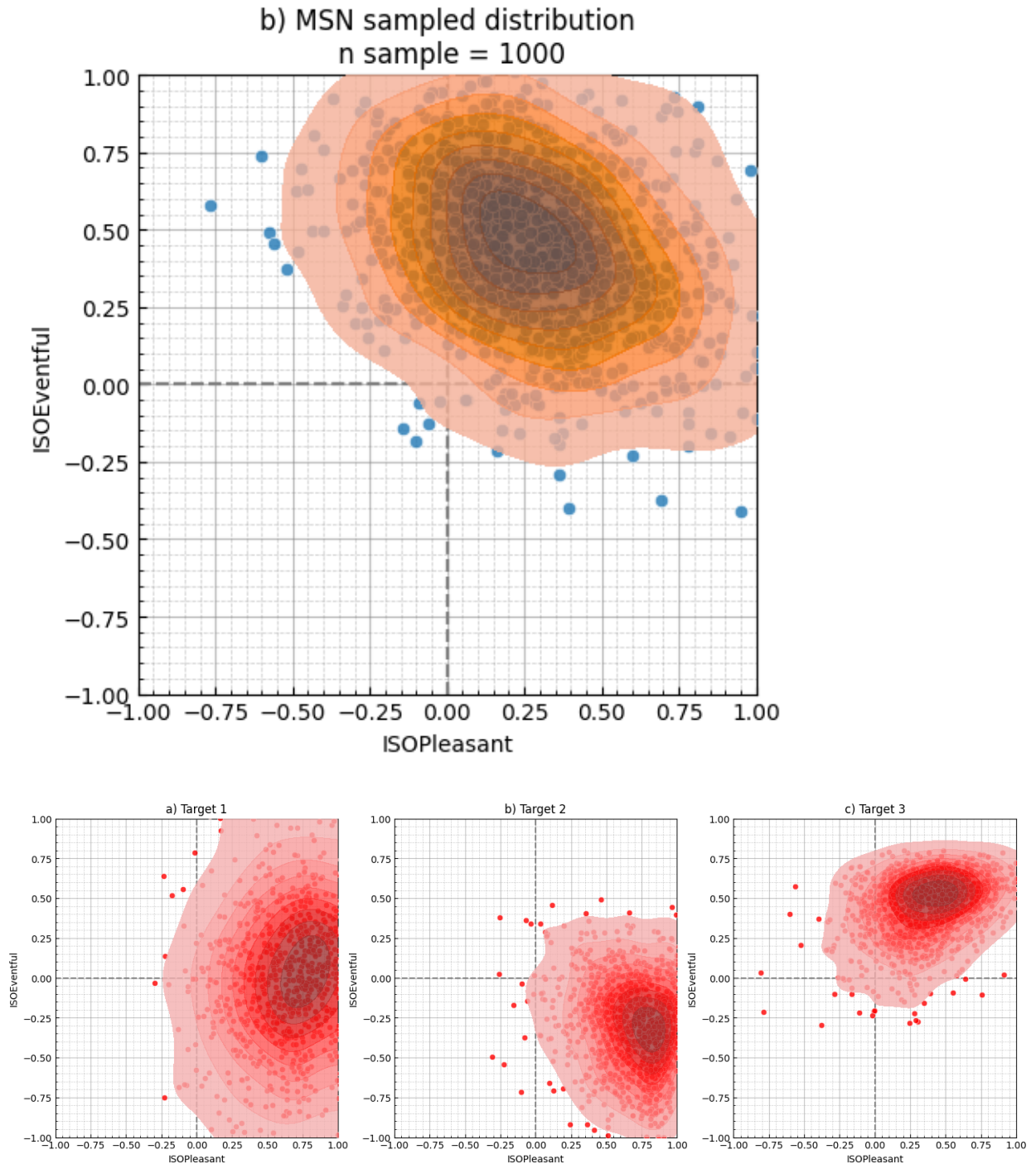


Figure 2: Example of defining and sampling from three arbitrary bespoke targets.

Table 3: Kolmogorov-Smirnov test comparing the empirical test distribution (Piazza San Marco) against three soundscape target distributions.

Target	D	p
tgt_1	0.69	2.15802e-27
tgt_2	0.83	4.79381e-39
tgt_3	0.28	4.79381e-39

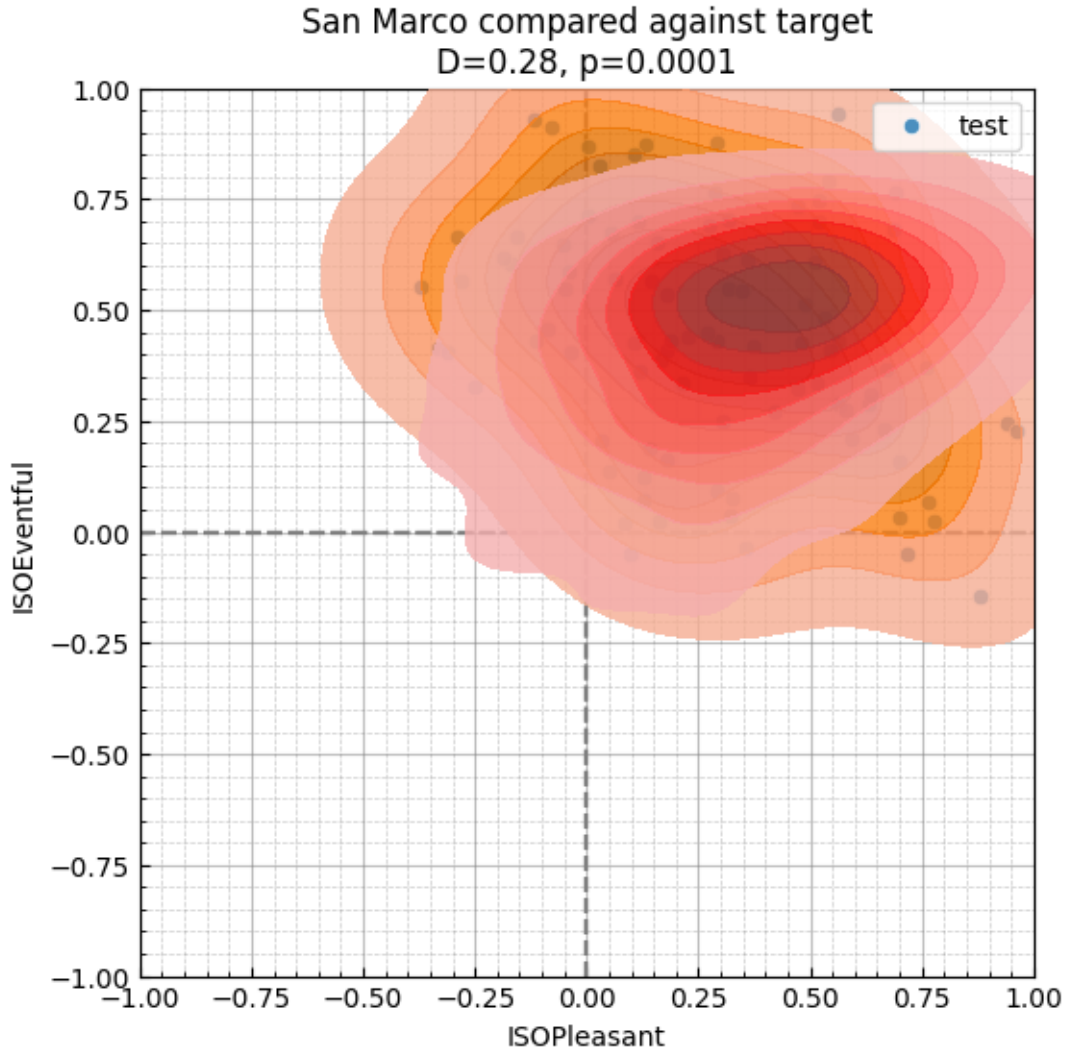


Table 4: SPI scores and rankings for the soundscapes of locations included in the International Soundscape Database (ISD).

Ranking	$SPI_1$ (pleasant)	$SPI_2$ (calm)	$SPI_3$ (vibrant)
1	70 RegentsParkFields	62 CampoPrincipe	72 SanMarco
2	68 CarloV	55 CarloV	62 TateModern
3	65 RegentsParkJapan	51 RegentsParkFields	59 StPaulsCross
4	60 CampoPrincipe	48 PlazaBibRambla	58 Noorderplantsoen

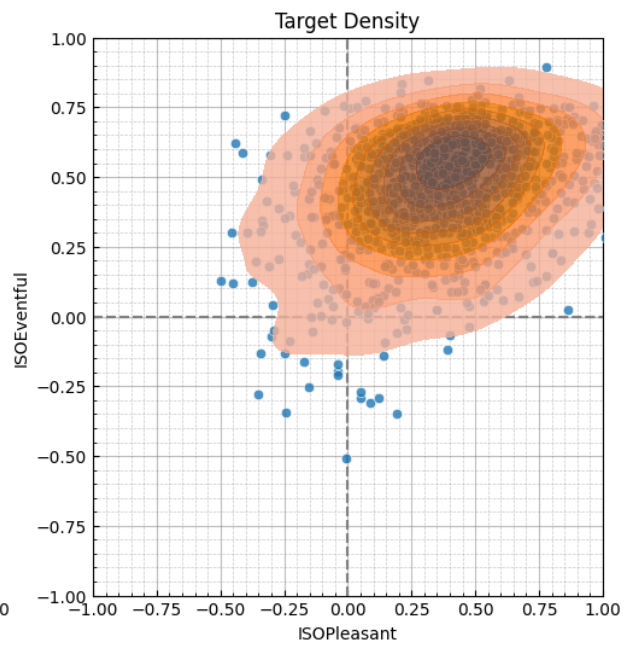
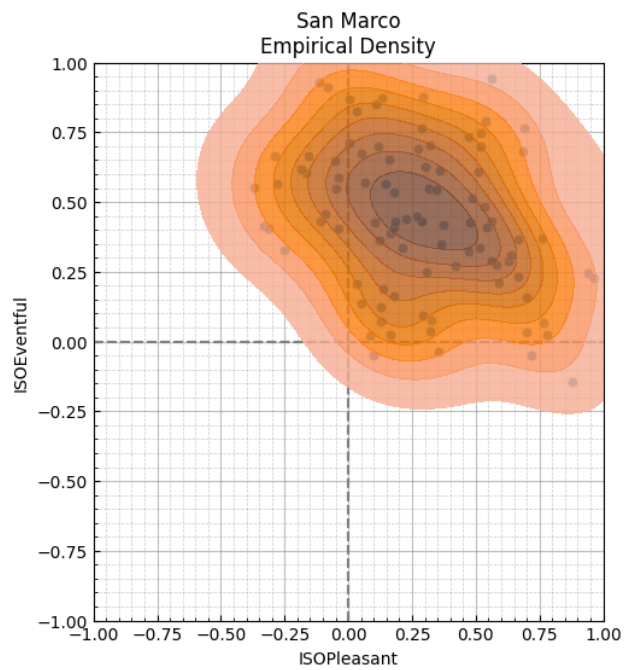
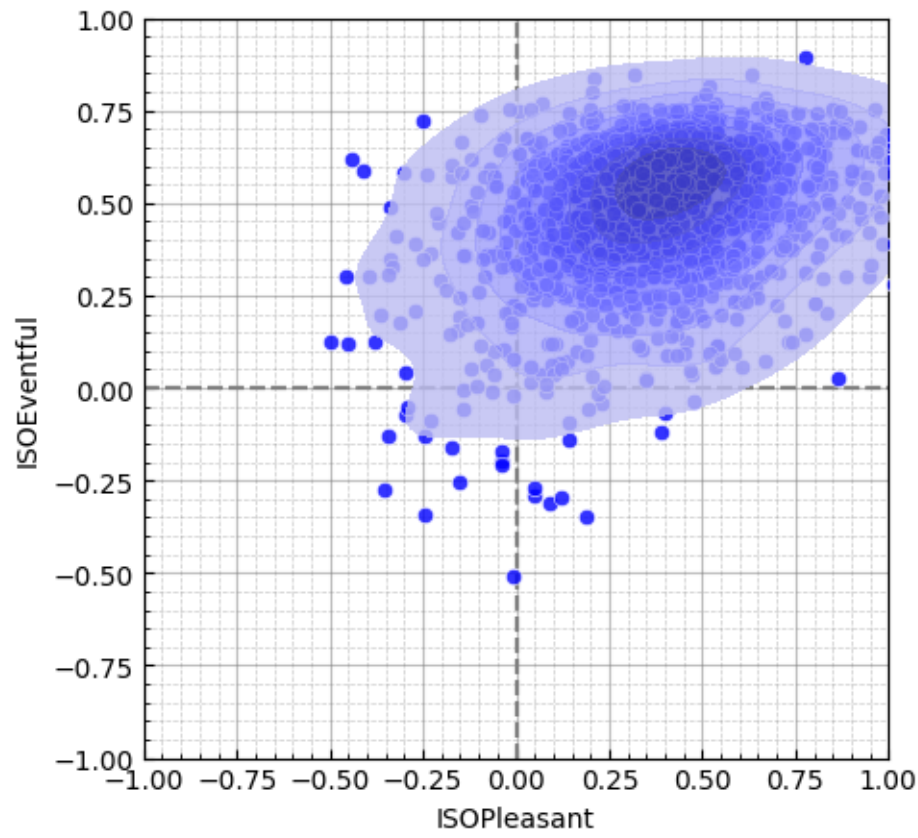


Table 4: SPI scores and rankings for the soundscapes of locations included in the International Soundscape Database (ISD).

Ranking	$SPI_1$ (pleasant)	$SPI_2$ (calm)	$SPI_3$ (vibrant)
5	60 RussellSq	44 MarchmontGarden	54 PancrasLock
6	59 MarchmontGarden	44 MonumentoGaribaldi	54 TorringtonSq
7	58 PlazaBibRambla	41 RussellSq	48 StPaulsRow
8	58 MonumentoGaribaldi	38 RegentsParkJapan	47 RussellSq
9	56 PancrasLock	38 PancrasLock	47 MiradorSanNicolas
10	49 StPaulsCross	34 MiradorSanNicolas	41 CamdenTown
11	45 TateModern	30 TateModern	41 CarloV
12	45 StPaulsRow	30 StPaulsCross	36 MonumentoGaribaldi
13	40 MiradorSanNicolas	29 StPaulsRow	34 MarchmontGarden
14	38 Noorderplantsoen	27 TorringtonSq	34 PlazaBibRambla
15	35 TorringtonSq	16 SanMarco	33 CampoPrincipe
16	30 SanMarco	15 Noorderplantsoen	32 EustonTap
17	20 CamdenTown	14 CamdenTown	26 RegentsParkFields
18	15 EustonTap	12 EustonTap	26 RegentsParkJapan

RegentsParkFields 70  
 CarloV 68  
 RegentsParkJapan 65  
 CampoPrincipe 60  
 RussellSq 60  
 MarchmontGarden 59  
 PlazaBibRambla 58  
 MonumentoGaribaldi 58  
 PancrasLock 56  
 StPaulsCross 49  
 TateModern 45  
 StPaulsRow 45  
 MiradorSanNicolas 40  
 Noorderplantsoen 38  
 TorringtonSq 35  
 SanMarco 30  
 CamdenTown 20  
 EustonTap 15

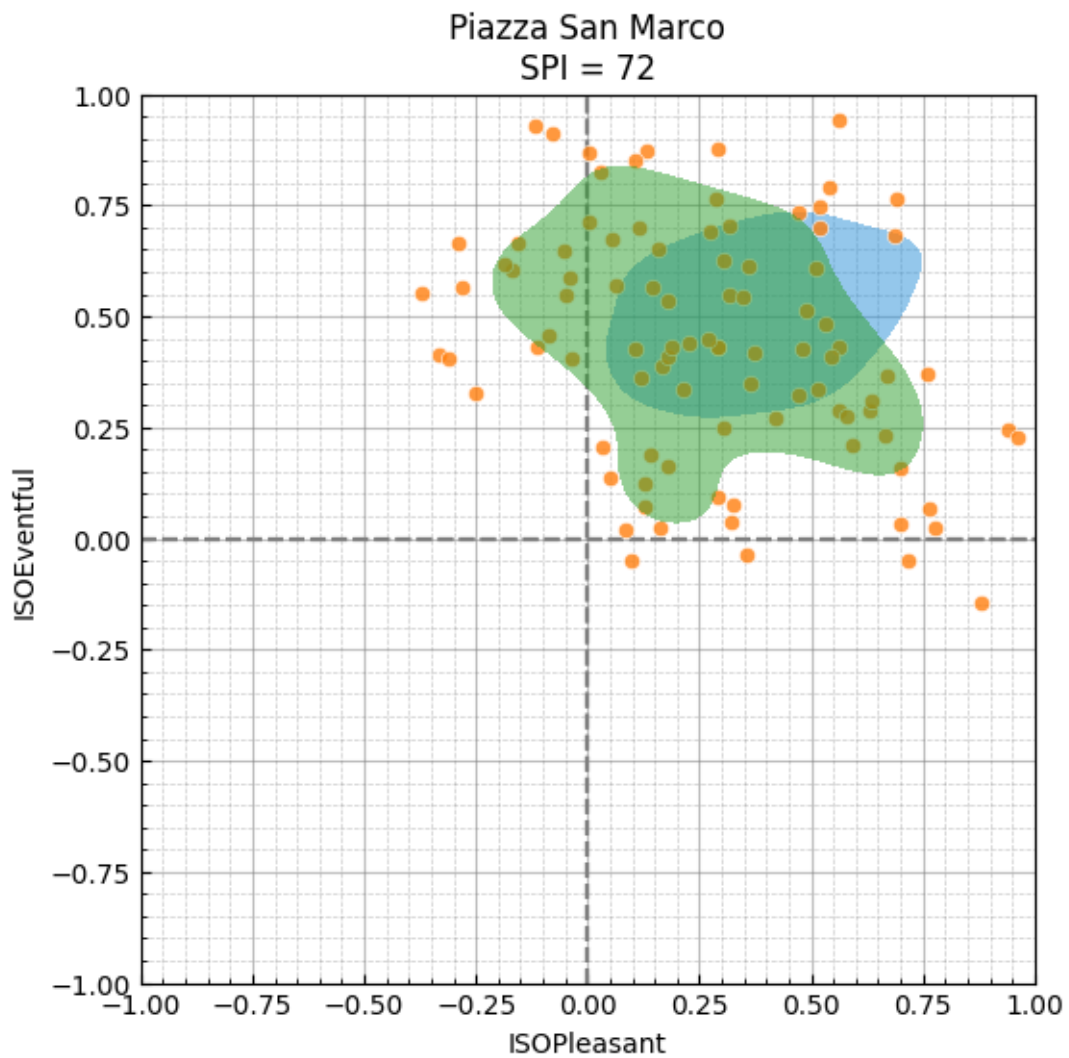
Name: tgt\_1, dtype: int64



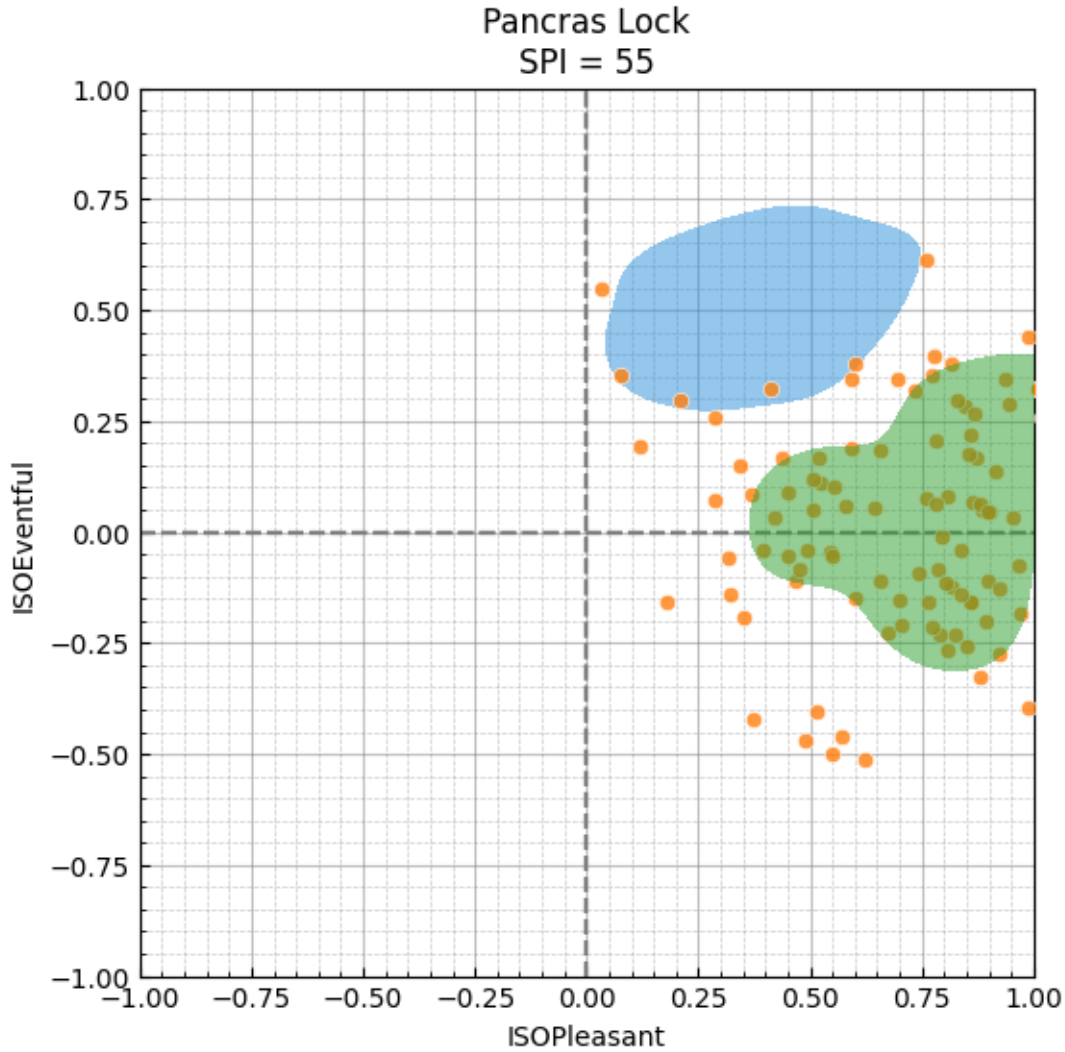
Once the target is defined, we will generate a set of points that represent the target distribution.

Now that our target has been defined, we can calculate the SPI for a given set of responses. We will use the responses from Piazza San Marco in Venice, Italy, as an example.

San Marco SPI = 72



We can compare this against another location, such as St Pancras Lock.



SPI scores assessed against a target should not inherently be considered a measure of the quality of the soundscape - instead it reflects the degree to which the soundscape matches the target. A high SPI score does not necessarily mean that the soundscape is of high quality, but rather that the soundscape is of high quality *according to the target*.

The  $SPI_{bespoke}$  thus provides a method for scoring and ranking the success of a soundscape design against the designer's goals. Sticking with our defined target, we can assess all of the locations in the ISD and see which locations best match our target.

	SPI
SanMarco	72
TateModern	61
StPaulsCross	61
Noorderplantsoen	58
PancrasLock	55
TorringtonSq	55
StPaulsRow	47

	SPI
RussellSq	47
MiradorSanNicolas	47
CamdenTown	44
CarloV	40
MonumentoGaribaldi	38
MarchmontGarden	35
PlazaBibRambla	35
CampoPrincipe	33
EustonTap	30
RegentsParkFields	27
RegentsParkJapan	26

Assessed against a different target would result in a different ranking:

Fitted from direct parameters.

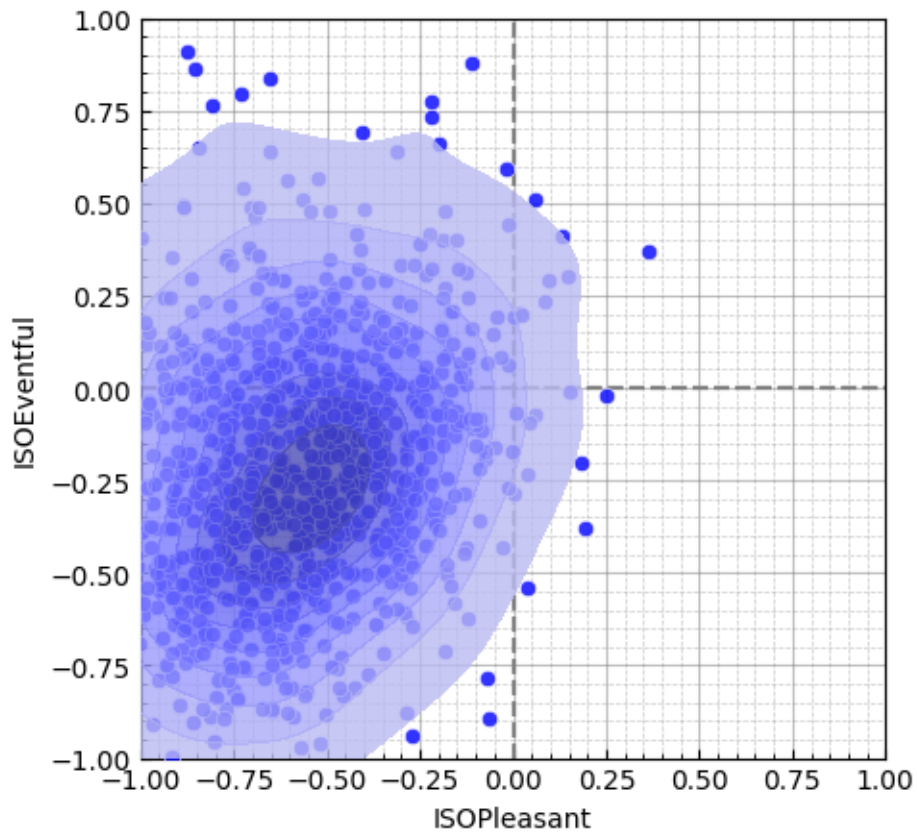
Direct Parameters:

xi: [-0.5 -0.5]

omega: [[0.1 0. ]  
[0. 0.2]]

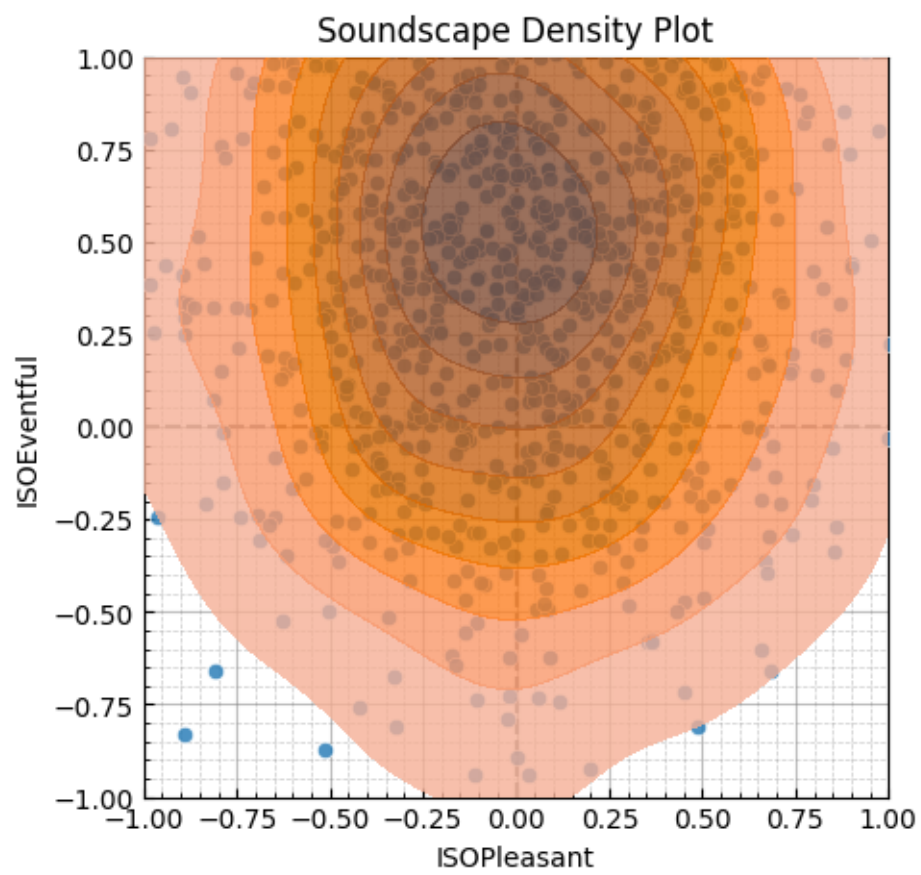
alpha: [-0.85 1.5 ]

None



	SPI
EustonTap	31
CamdenTown	22
MarchmontGarden	19
TorringtonSq	19
PancrasLock	17
PlazaBibRambla	15
StPaulsRow	15
StPaulsCross	10
CampoPrincipe	8
SanMarco	8
TateModern	7
RussellSq	6
CarloV	6
RegentsParkJapan	6
MiradorSanNicolas	5
MonumentoGaribaldi	3
Noorderplantsoen	3
RegentsParkFields	2





References