Difference between two rates

```
import os

if "KERAS_BACKEND" not in os.environ:
    # set this to "torch", "tensorflow", or "jax"
    os.environ["KERAS_BACKEND"] = "jax"

import matplotlib.pyplot as plt
import numpy as np
import bayesflow as bf
```

```
INFO:bayesflow:Using backend 'jax'
```

In this section we will estimate the difference between two binomial rates according to the following model:

$$
\begin{aligned}
k_1 &\sim \text{Binomial}(\theta_1, n_1) \\
k_2 &\sim \text{Binomial}(\theta_2, n_2) \\
\theta_1 &\sim \text{Beta}(1, 1) \\
\theta_2 &\sim \text{Beta}(1, 1) \\
\delta &\leftarrow \theta_1 - \theta_2
\end{aligned}
\tag{1}
$$

Simulator

```
def context():
    return dict(
        n=np.random.randint(1, 101, size=2)
    )
```

```
def prior():
    theta=np.random.beta(a=1, b=1, size=2)

    return dict(theta=theta, delta=theta[0]-theta[1])

def likelihood(n, theta):
    k=np.random.binomial(n=n, p=theta)

    return dict(k=k)

simulator = bf.make_simulator([context, prior, likelihood])
```

Approximator

```
adapter=(
    bf.Adapter()
    .constrain("delta", lower=-1, upper=1)
    .rename("delta", "inference_variables")
    .concatenate(["k", "n"], into="inference_conditions")
)
```

```
workflow=bf.BasicWorkflow(
    simulator=simulator,
    adapter=adapter,
    inference_network=bf.networks.CouplingFlow()
)
```

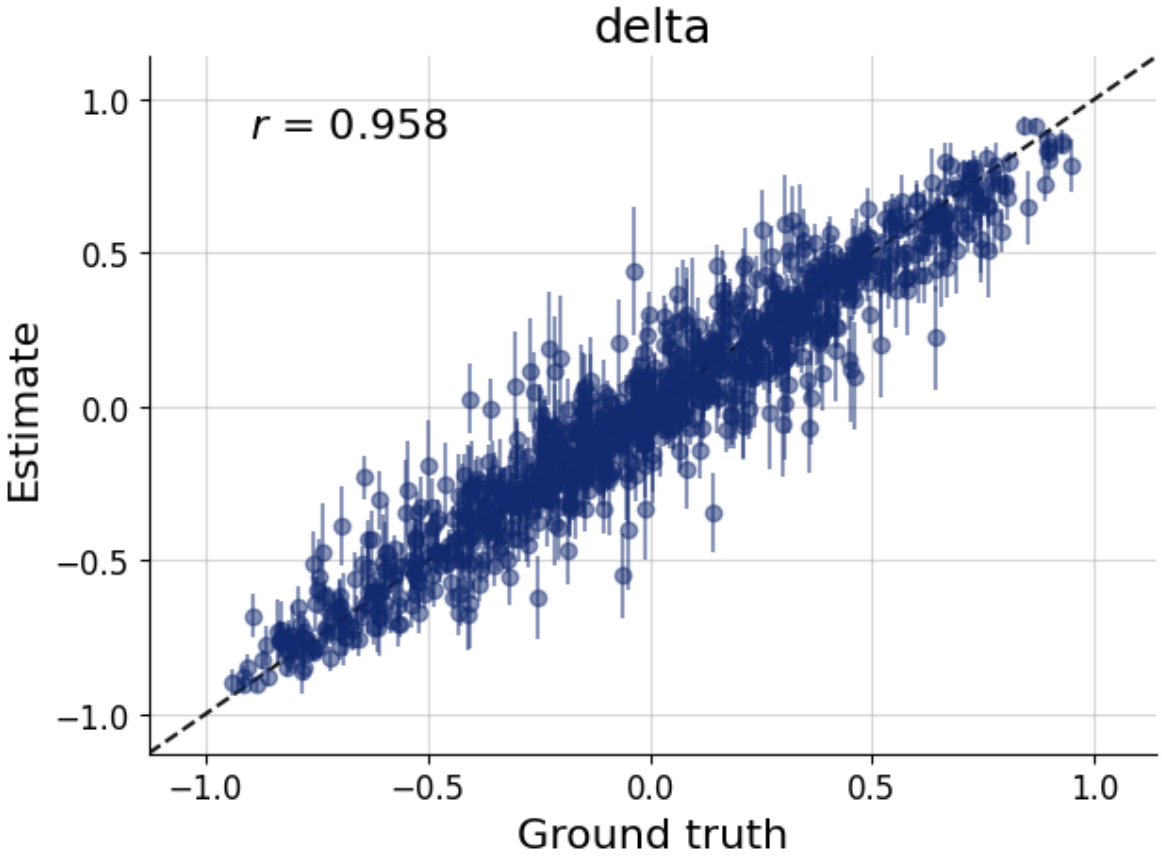
Training

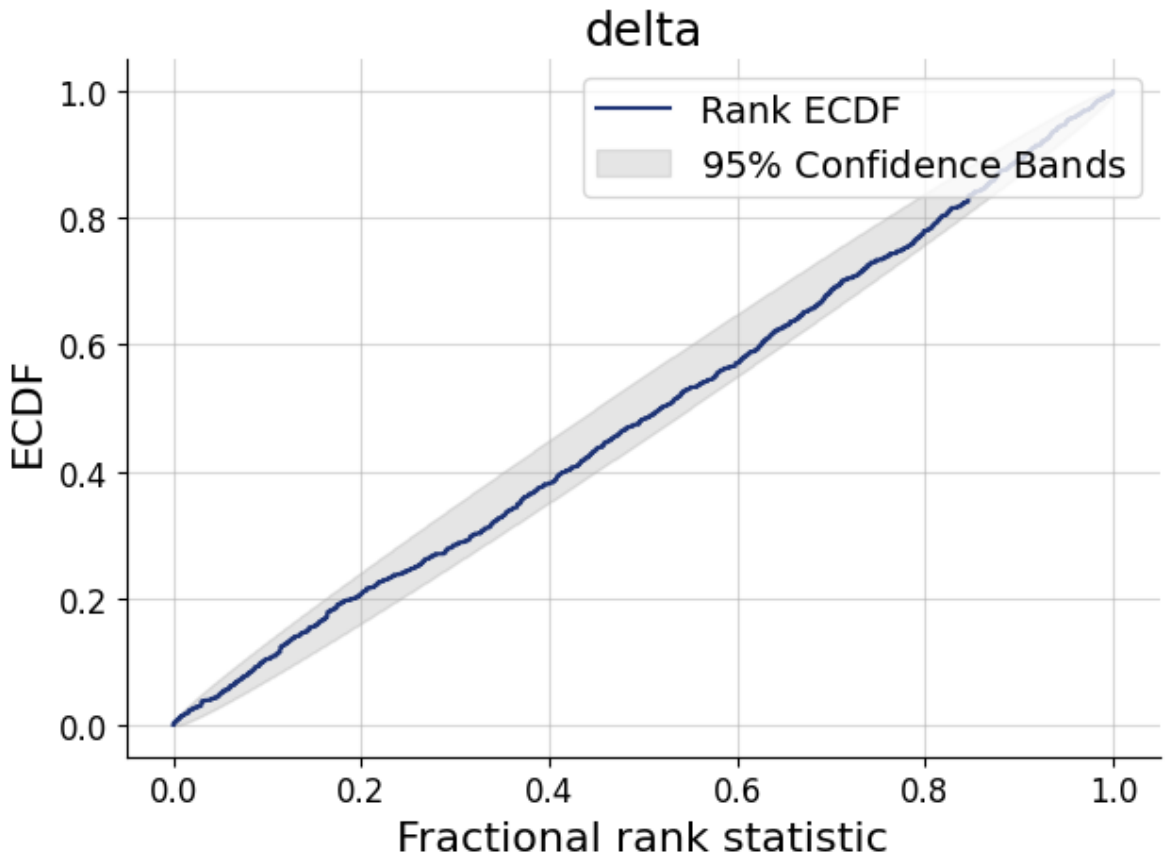
```
history=workflow.fit_online(epochs=20, batch_size=512)
```

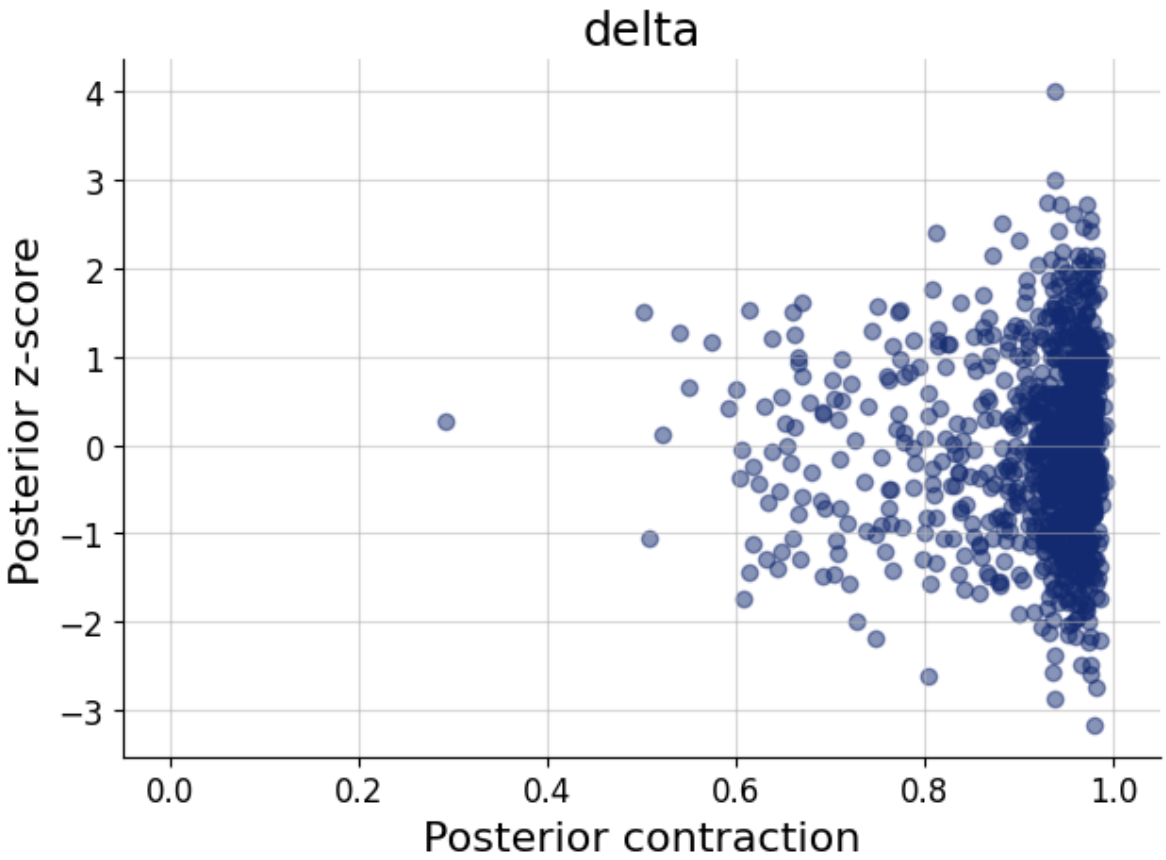
Validation

```
test_data=simulator.sample(1000)
figs=workflow.plot_default_diagnostics(test_data=test_data, num_samples=500)
```


Loss Trajectory
Training
Training (Moving Average)
Value
Training epoch #


delta
r = 0.958
Estimate
Ground truth


delta
Rank ECDF
95% Confidence Bands
ECDF
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Fractional rank statistic



Inference

Here we estimate the parameters with $k_1 = 5$, $k_2 = 7$, $n_1 = n_2 = 10$.

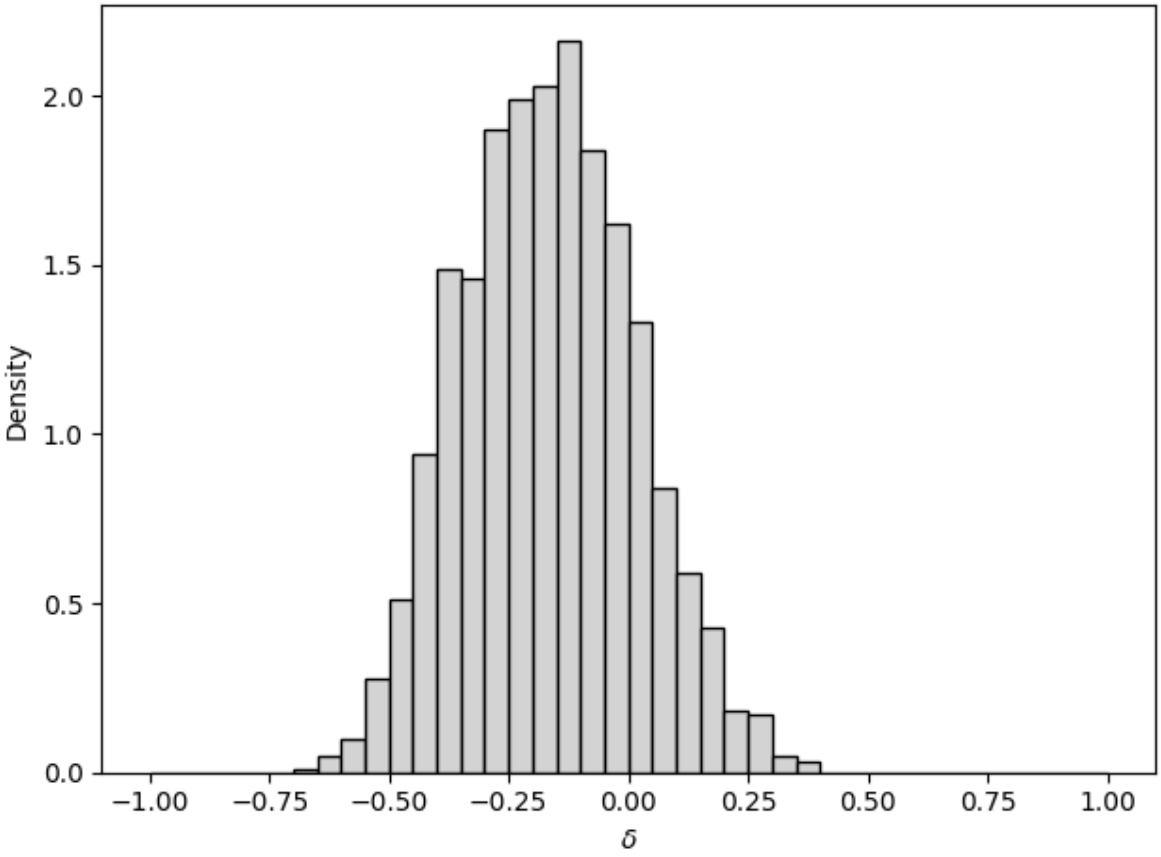
```
inference_data=dict(
    k = np.array([[5, 7]]),
    n = np.array([[10, 10]])
)
```

```
samples=workflow.sample(num_samples=2000, conditions=inference_data)
```

```
workflow.samples_to_data_frame(samples).describe()
```

	delta
count	2000.000000
mean	-0.166482
std	0.178362
min	-0.659297
25%	-0.296740
50%	-0.171059
75%	-0.041115
max	0.390967

```
plt.hist(samples["delta"].flatten(), density=True, color="lightgray", edgecolor="black", bins
plt.xlabel(r"$\delta$")
plt.ylabel("Density")
plt.tight_layout()
```



Lee, M. D., & Wagenmakers, E.-J. (2013). *Bayesian Cognitive Modeling: A Practical Course*. Cambridge University Press.