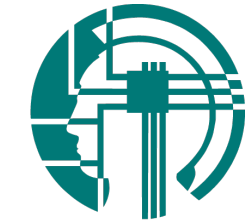


Lecture 10: Project

Marcel Binz & Eric Schulz

June 28, 2022

Max Planck Institute for Biological Cybernetics
Computational Principles of Intelligence Lab

Plan for Today

Project Logistics

Experiment Summary

Data Collection

Expectations

Further Potential Ideas

What's Next?

Project Logistics

Project

You will analyze data from an experiment using the tools learned in the lecture.

We collect the data today.

The final data-set will be available later this evening via Ilias.

You can start analyzing right away once the data is available.

Work in groups of up to 3.

Grading

You submit a short research paper (around 6-7 pages) and give a 15 minute presentation.

Your final grade will be a combination of a paper grade (60%) and a presentation grade (40%).

We will provide more detailed grading criteria closer to the deadline.

Supervision

Franziska and Tankred are your main points of contacts.

Each of them will reserve a two hour slot per week for helping you with any questions.

You can book 30 minute slots as needed (recommended once per week, at least in the beginning).

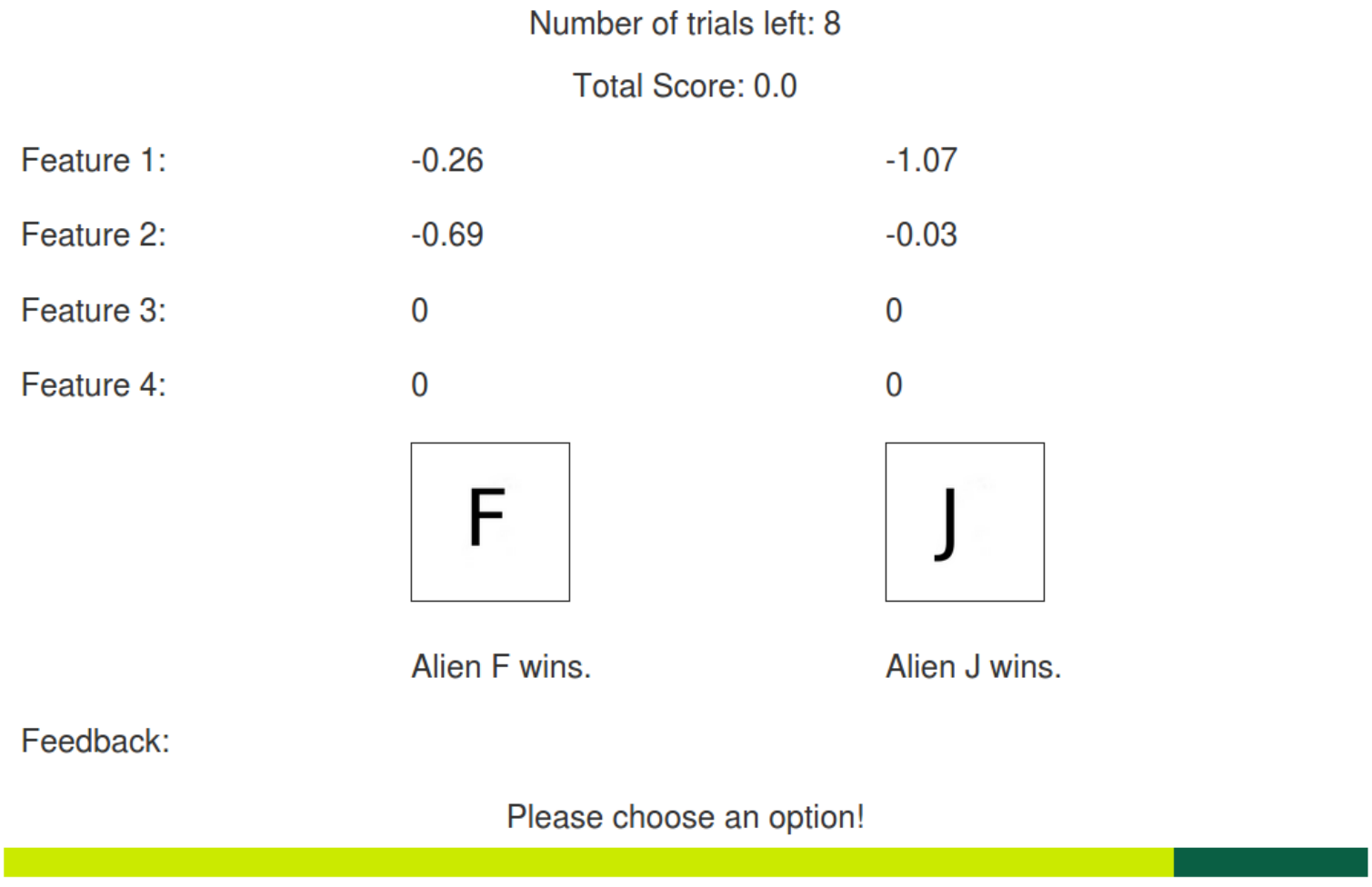
Meet on Zoom or in person at the MPI.

They will redirect you to Eric or me if needed.

Experiment Summary

Experiment

Two-alternative forced-choice task:



Conditions

We vary the number of features $N \in \{2, 3, 4\}$ within subjects.

The decision-time is varied between $T \in \{3s, 6s\}$ within subjects.

Each subject does 5 tasks of length 10 per setting.

Decision-time is manipulated in blocks (i.e., the first half of the experiment is either slow or fast; counterbalanced between subjects).

The order of the number of features is randomized.

Data-generating process

The data for each round was generated as follows:

$$
\begin{aligned}
\mathbf{w} &\sim \mathcal{N}(0, \mathbf{I}) \\
\mathbf{x}_{t,F} &\sim \mathcal{N}(0, \mathbf{I}) \\
\mathbf{x}_{t,J} &\sim \mathcal{N}(0, \mathbf{I}) \\
\mathbf{y}_{t,F} &= \mathbf{w}^\top \mathbf{x}_{t,F} \\
\mathbf{y}_{t,J} &= \mathbf{w}^\top \mathbf{x}_{t,J}
\end{aligned}
$$

Participants are not informed about this data-generating process.

We created 20 files that each contain 30 rounds (i.e., a single experiment).

Each subject was randomly assiged to one of the files.

Data

num_features	task	trial	w0	w1	w2	w3	xf0	xf1	xf2	xf3	xj0	xj1	xj2	xj3	yf	yj	slow	J_pressed	decision_time
2	1	1	0.2658892572	-0.3623841703	0	0	-1.1444094181	1.241232276	0	0	-0.7667886019	0.4900366366	0	0	-0.7540891171	-0.3814623654	1	0	2192
2	1	2	0.2658892572	-0.3623841703	0	0	-0.5390020013	-0.3786033094	0	0	1.6181612015	0.7346971035	0	0	-0.0061149923	0.1640090942	1	1	939
2	1	3	0.2658892572	-0.3623841703	0	0	-0.2602435946	-1.0037280321	0	0	-0.4549027681	0.8952396512	0	0	0.2945391834	-0.4453744292	1	1	2348
2	1	4	0.2658892572	-0.3623841703	0	0	-0.2408819348	-1.4924048185	0	0	-0.2947974205	0.2696490586	0	0	0.476775974	-0.1761000156	1	0	2660
2	1	5	0.2658892572	-0.3623841703	0	0	1.7701907158	1.3329899311	0	0	-0.1165423691	0.3223896921	0	0	-0.0123797562	-0.1478162855	1	0	764
2	1	6	0.2658892572	-0.3623841703	0	0	0.0110472795	0.417493999	0	0	-0.3336547613	-0.7634206414	0	0	-0.1483558565	0.1879363358	1	0	1628
2	1	7	0.2658892572	-0.3623841703	0	0	0.3628984392	0.6152717471	0	0	0.111696966	-0.4516782165	0	0	-0.1264739484	0.1933800578	1	1	3093
2	1	8	0.2658892572	-0.3623841703	0	0	-0.3167894185	0.2812200189	0	0	-0.9767736197	0.6762996912	0	0	-0.186140582	-0.504793942	1	0	3596
2	1	9	0.2658892572	-0.3623841703	0	0	3.1947131157	-0.9606922865	0	0	0.3179793358	-0.7927073836	0	0	1.1975796223	0.3718118966	1	0	2162
2	1	10	0.2658892572	-0.3623841703	0	0	-0.0665383339	-0.7990768552	0	0	-1.610956192	0.4160243869	0	0	0.2718809843	-0.5790965557	1	0	2146
3	2	1	1.2032494545	-0.4108892679	-0.9608332515	0	0.4626556039	0.7134649754	1.5977290869	0	-0.3080119789	0.369241029	0.8739486933	0	-1.2716162205	-1.3620513678	1	0	3197
3	2	2	1.2032494545	-0.4108892679	-0.9608332515	0	0.9711865187	-0.4836977124	-0.1883638054	0	-0.2034544945	-0.7153841257	-1.8640440702	0	1.548312068	1.8401726484	1	0	3987
3	2	3	1.2032494545	-0.4108892679	-0.9608332515	0	0.4996956587	-1.680418849	0.5308663845	0	-0.1054704264	-0.3856794238	-0.7783710957	0	0.7816504836	0.7794491053	1	0	802
3	2	4	1.2032494545	-0.4108892679	-0.9608332515	0	1.4348603487	1.9120627642	-0.028084904	0	-0.2422170788	-1.4419404268	0.7718979716	0	0.9678337574	-0.4406349659	1	0	1037
3	2	5	1.2032494545	-0.4108892679	-0.9608332515	0	-0.786783576	-1.2360821962	0.2799559534	0	-0.537361443	0.4189410508	-0.0990958735	0	-0.7077950239	-0.7235036492	1	1	3302
3	2	6	1.2032494545	-0.4108892679	-0.9608332515	0	0.3282533586	0.4509314597	0.2504540384	0	0.4245001972	-2.413957119	-0.5472255349	0	-0.0309567899	2.0284411907	1	1	899
3	2	7	1.2032494545	-0.4108892679	-0.9608332515	0	0.0993033573	1.1846628189	1.0811839104	0	0.504519999	1.4748356342	-0.8134375215	0	-1.4061160088	0.7826471329	1	1	1054
3	2	8	1.2032494545	-0.4108892679	-0.9608332515	0	0.7334067822	0.9720897079	-0.0036462042	0	-1.9813051224	0.8794110417	0.9803906679	0	0.4865534902	-3.6873369217	1	0	739
3	2	9	1.2032494545	-0.4108892679	-0.9608332515	0	-0.3936625421	-0.3219719529	-1.1460751295	0	1.2463451624	-1.0842013359	-0.8275060058	0	0.7598076463	2.7402462959	1	0	1492
3	2	10	1.2032494545	-0.4108892679	-0.9608332515	0	1.8364927769	0.2835374177	-0.2490750104	0	-0.0329621062	1.3831335306	0.5070220232	0	2.3325760365	-1.0951399803	1	0	868
3	3	1	-0.4361052811	-0.4570937753	-2.0141820908	0	-0.8585326076	-0.8246580362	1.5860008001	0	0.4946114719	0.2332803458	1.4074699879	0	-2.4431378841	-3.1572344303	1	1	3806
3	3	2	-0.4361052811	-0.4570937753	-2.0141820908	0	-0.184770897	0.9321793318	-0.9742520452	0	1.0691906214	1.4052978754	-0.3347022831	0	1.6168072224	-0.4344812036	1	0	2516
3	3	3	-0.4361052811	-0.4570937753	-2.0141820908	0	-0.3455687165	0.5691988468	2.52287817	0	0.0434801094	-1.6871608496	-0.6203683019	0	-5.1910085678	2.0017635822	1	1	2372
3	3	4	-0.4361052811	-0.4570937753	-2.0141820908	0	-0.9672344923	-1.9936001301	2.317918539	0	-0.5633419752	-0.9319443703	-0.3442852199	0	-3.3356318474	1.3651155233	1	0	1108
3	3	5	-0.4361052811	-0.4570937753	-2.0141820908	0	-0.5114772916	0.2843758464	1.3496943712	0	0.2797493041	-0.3741668761	0.8653780222	0	-2.6254587173	-1.6939996481	1	1	837
3	3	6	-0.4361052811	-0.4570937753	-2.0141820908	0	0.5220605135	2.0250449181	-0.4641208649	0	1.4880919456	1.0074005127	0.866097033	0	-0.2184848189	-2.8539185524	1	1	1332
3	3	7	-0.4361052811	-0.4570937753	-2.0141820908	0	0.1578592211	-0.6453623772	-0.3148650825	0	-0.5812572837	-0.2926484048	0.9694072008	0	0.8603435159	-1.5653054714	1	0	1709
3	3	8	-0.4361052811	-0.4570937753	-2.0141820908	0	2.1522393227	-1.2462260723	1.0307190418	0	-0.1435328871	0.903044045	1.6403460503	0	-2.4450163841	-3.6541359425	1	0	2181
3	3	9	-0.4361052811	-0.4570937753	-2.0141820908	0	0.2293807119	-0.2406851649	0.099731639	0	-2.7186508179	-1.0058659315	0.5651760697	0	-0.1908961236	0.5070254803	1	0	3180
3	3	10	-0.4361052811	-0.4570937753	-2.0141820908	0	0.3450422883	1.2261773348	0.1731979251	0	1.2408201694	0.5566526651	-0.9254871011	0	-1.0598049164	1.0685288906	1	1	3324
2	4	1	1.1996746063	-0.6602859497	0	0	-0.3486043811	-0.3616447449	0	0	0.9444773197	0.2602933645	0	0	-0.1794228703	0.9611974359	1	1	2893
2	4	2	1.1996746063	-0.6602859497	0	0	-0.9808114767	1.9908012152	0	0	0.5860420465	-0.8500311971	0	0	-2.4911527634	1.2643233538	1	0	1765
2	4	3	1.1996746063	-0.6602859497	0	0	0.0817938223	-0.1920656413	0	0	-0.3801752031	0.6345770359	0	0	0.224944219	-0.8750888705	1	0	860
2	4	4	1.1996746063	-0.6602859497	0	0	0.6072872281	0.4847472012	0	0	1.712023139	-0.166977942	0	0	0.4084752798	2.1641237736	1	1	901
2	4	5	1.1996746063	-0.6602859497	0	0	-0.6571445465	-0.1280414909	0	0	0.0090289107	1.1998841763	0	0	-0.703815639	-0.7814348936	1	1	884
2	4	6	1.1996746063	-0.6602859497	0	0	0.3687122166	-1.0664354563	0	0	2.4211883545	1.2510126829	0	0	1.1464869976	2.0786120892	1	1	885
2	4	7	1.1996746063	-0.6602859497	0	0	0.5167723298	0.3308488131	0	0	0.3519947827	0.867354393	0	0	0.4015038311	-0.1504227072	1	0	1867
2	4	8	1.1996746063	-0.6602859497	0	0	-0.9269423485	-0.1442142427	0	0	3.065482378	2.4872443676	0	0	-1.0168066025	2.0352888107	1	1	877
2	4	9	1.1996746063	-0.6602859497	0	0	-0.6625127792	-0.9988594055	0	0	1.8282440901	-0.5091176033	0	0	-0.1352669001	2.5294613838	1	1	1164
2	4	10	1.1996746063	-0.6602859497	0	0	0.8462463617	-0.1997689754	0	0	1.1379014254	0.4378280044	0	0	1.1471248865	1.0760197639	1	0	772
4	5	1	-0.0287362151	0.2132585198	-2.2815685272	-0.1888890117	0.9547708631	-0.8158378005	1.5957664251	-0.4090990722	0.797699213	-0.5559232831	-1.2388583422	0.5070442557	-3.7649970055	2.5892868042	1	0	2421
4	5	2	-0.0287362151	0.2132585198	-2.2815685272	-0.1888890117	0.0757495165	-2.661149025	0.6440638304	-0.3397624791	0.6189219356	-0.9379668236	-0.3905736506	-1.2158676386	-1.9749877453	0.902969718	1	1	1085
4	5	3	-0.0287362151	0.2132585198	-2.2815685272	-0.1888890117	1.7086719275	-1.057262063	0.6878268123	1.1231520176	0.1829665005	1.2546869516	-0.2272648066	-2.2002928257	-2.0560460091	1.1964462996	1	1	732
4	5	4	-0.0287362151	0.2132585198	-2.2815685272	-0.1888890117	1.3769539595	-0.5550884008	0.9699192047	3.281427145	-0.0826568678	2.5254333019	-0.6624817848	-0.9924193621	-2.9907083511	2.2399001122	1	1	701
4	5	5	-0.0287362151	0.2132585198	-2.2815685272	-0.1888890117	0.2593949437	-1.82977736	-0.5727994442	1.3240506649	0.4972245693	-2.4644784927	0.1521692872	0.3484019637	0.6591129303	-0.9528533816	1	0	684

Data Collection

Data collection

Go to: https://kyblab.tuebingen.mpg.de/experiment_ccs2022/banditexperiment/

and do the experiment.

It will save a .json file at the end of the experiment to your local machine, please upload that file in Ilias.

We will add data from a bunch of people from our a lab to the mix.

Expectations

Expectations

Your analysis should contain three parts:

1. Behavioral analysis
2. Parameter fitting
3. Model comparison

Behavioral analysis

Here are questions that you should answers:

- Do participants perform better than chance?
- Do they improve over trials within each round?
- Do they improve over rounds?
- How does the number of observed features affect performance?
- How does time pressure affect performance?

Parameter fitting

Fit, at the least, parameters of the Kalman filter and the Rescorla Wagner model with an appropriate error model.

Look at the resulting parameters and try to answer the following questions:

- Does time pressure lead to slower learning?
- Does time pressure lead to more noisy decisions?

Model comparison

Perform a model comparison that includes, at the least, the Kalman filter and the Rescorla Wagner model with an appropriate error model.

Try to answer the following questions:

- Which model explains the human data best?
- Does time pressure lead to simpler learning strategies?

Further Potential Ideas

Further potential ideas

The previously outlined analysis is the requirement to obtain a solid passing grade.

Beyond that you can explore additional ideas as you like.

You may think of other hypothesis that you would like to test:

- Do people discretize observations?
- Do they learn from binary (right/wrong) or continuous feedback?
- ...

You may try out modelling the data with additional models.

Additional models

Learning:

- Heuristics (one-reason decision-making, equal weighting, . . .) [1].
- Neural networks [1].
- Exemplar-based models [2].

Decision-making:

- Drift diffusion models [3].
- Resource-rational models [4].

Many more options possible!

What’s Next?

What's next?

Meet regularly with Franziska and Tankred.

Three more lectures:

- 05.07. Writing Advice & Plotting
- 12.07. Recent work in cognitive science I
- 19.07. Recent work in cognitive science II
- 26.07. No lecture

No more fixed tutorial slot on Fridays.

Deadline papers: 04.10.2022, 14:00
Presentations: 04.10.2022, 14:00

Resources

[1] Binz, M., Gershman, S.J., Schulz, E. and Endres, D., 2022. Heuristics from bounded meta-learned inference. Psychological review.

[2] Schulz, E., Speekenbrink, M. and Krause, A., 2018. A tutorial on Gaussian process regression: Modelling, exploring, and exploiting functions. Journal of Mathematical Psychology, 85, pp.1-16.

[3] Pedersen, M.L., Frank, M.J. and Biele, G., 2017. The drift diffusion model as the choice rule in reinforcement learning. Psychonomic bulletin & review, 24(4), pp.1234-1251.

[4] Lai, L. and Gershman, S.J., 2021. Policy compression: An information bottleneck in action selection. In Psychology of Learning and Motivation (Vol. 74, pp. 195-232). Academic Press.