A LARGE-SCALE COMPILATION OF CHOICE AND RESPONSE-TIME DATA IN INTERTEMPORAL CHOICE

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Hannah Pongratz[*]
Department of Psychology
University of Mannheim
68151 Mannheim, Germany
hannah.pongratz@uni-mannheim.de

Martin Schoemann[*]
Department of Psychology
Dresden University of Technology
01062 Dresden, Germany
martin.schoemann@tu-dresden.de

ABSTRACT

The study of intertemporal choices (ITC) plays a vital role in psychological and behavioral economics research. Models of intertemporal choice (ITC) have traditionally focused on choices. A growing interest in the underlying cognitive processes has initiated the development of process models. Process models require process data, and yet ITC research has largely overlooked even the simplest process data – response times (RTs). We present a database of choices and response times from 105 ITC studies with $12,281$ subjects and $1,213,676$ trials. In addition to behavioral data, we collected various methodological and sample information (e.g., task procedure, incentivization). The objective of the ITC Database is to facilitate the development of more nuanced and accurate theories of ITC. The ITC Database is open to ongoing submissions and is projected to expand continuously.

Keywords intertemporal choice · choice-rt data · database · process data · decision-making

[*]These authors contributed equally. Analysis scripts to reproduce all tables and figures of the article are available via https://osf.io/3wsae/. Corresponding authors: H. Pongratz & M. Schoemann

1 Background & Summary

Intertemporal choice (*ITC*) and the corresponding phenomenon of temporal (or delay) discounting have been extensively studied across disciplines, with roots in economics and subsequent exploration in psychology. Initially, economic models of ITC focused on normative or descriptive accounts of ITC behavior from a discounted utility perspective[1–3], neglecting the underlying psychological processes that drive temporal discounting[4–6]. In contrast, psychological investigations have sought to explain the cognitive and emotional mechanisms that influence ITC[7–10], often incorporating process-level assumptions or mechanisms into their models, such as alternative-wise vs. attribute-wise information processing[11–13] or evidence accumulation[14–17]. However, these psychological models have rarely moved beyond choice data, despite the need for process-level data to inform and validate assumptions and mechanisms in process models[18,19]. Response time (*RT*) data, as a basic form of process data[20], can complement choice data, putting important constraints on process models and hence providing valuable insights into the psychological processes underlying ITC[21].

The development of good process models requires the identification of robust effects on process data, and such effects are commonly robust to heterogeneity in the data[22,23]. Heterogeneity, in this context, refers to the variation in research results that exceeds expected sampling error, indicating a lack of coherence between applied concepts and observed data, which reflects an incomplete understanding of the phenomenon in particular[24,25] and a generalizability crisis in general[26]. To address this challenge, researchers can employ meta-studies, a recent research approach that involves creating a set of many small studies (micro-studies), each with a comparatively small number of participants or observations, all based on the same fundamental design but varying in their details to systematically replicate the same basic experiment[27–29]. This approach allows researchers to assess the phenomenon of interest while also examining the causal effects of moderators and ensuring generalizability[26,23].

While meta-studies offer an efficient and effective way to achieve the benefits of traditional replication and meta-analysis, they are typically conducted prospectively, requiring new data collection and incurring additional costs. However, meta-studies can also be conducted retrospectively, leveraging existing, yet unevaluated data, thereby eliminating the need for new data collection and associated costs. This retrospective approach is particularly well-suited for traditional basic experiments, such as those used to study ITC and delay discounting, where a large amount of data is already available but certain aspects or variables have remained unused. In such cases, retrospective meta-studies may be considered economically and ethically mandatory, as they can provide a comprehensive understanding of the phenomenon without incurring additional costs or burdening participants. Importantly, retrospective meta-studies can mitigate publication bias, as they may utilize aspects of the data from peer-reviewed publications that have not been previously evaluated, thereby providing a valid and representative picture of the research landscape. By harnessing the power of existing data, retrospective meta-studies can cover a significant proportion of the heterogeneity in ITC research, making them an attractive approach for researchers seeking to advance our understanding of this complex phenomenon.

To address this need, we have compiled a large-scale dataset of choices and response times in standard ITC tasks—the *ITC Database*—drawn from a diverse sample that covers a significant proportion of the methodological variance in ITC research. By making this compilation available, we aim to facilitate the advancement of ITC research by promoting the development of more nuanced and accurate theories of ITC. The compilation described here offers an opportunity for researchers to explore the complexities of ITC behavior, examine the robustness of effects across different experimental designs and participant populations, and develop more comprehensive process models that can account for the heterogeneity in ITC and delay discounting.

The compilation has not been used in any previous publication. However, the confidence database[30] is a similar endeavor, representing a comprehensive repository designed to facilitate the study of confidence across various cognitive and perceptual domains, for instance, to explore the relationship between confidence and accuracy in decision-making processes[31]. Our compilation and the confidence database represent a database that can be considered similar to what other large-scale endeavors, such as the Psychological Science Accelerator[32] or the Human Connectome Project[33], eventually produce – a highly representative and generalizable dataset of a set of phenomena of interest.

2 Methods

Our large-scale dataset of choices and response times in standard ITC tasks is a secondary dataset, compiled from existing publications that have investigated ITC behavior. To identify eligible datasets, we employed a three-step procedure. First, we conducted a systematic search for publications that may be associated with eligible datasets, aiming to exhaustively cover the relevant peer-reviewed literature. Next, we collected the data by identifying and accessing associated open data repositories or by contacting authors with formal data requests. Finally, we processed the collected data by structuring each dataset in a common format that can be easily imported and analyzed in multiple software packages. As part of this processing step, we also compiled relevant metadata for each dataset, providing essential context for subsequent analyses and ensuring the transparency and reproducibility of our dataset.

2.1 Systematic search

To identify eligible datasets, we followed a prespecified protocol (see https://osf.io/hsfuz) and conducted a systematic literature search (see Fig. 1), aiming to include any study that employed a standard ITC task and for which trial-level choice and response-time data may be obtained. We defined a standard ITC task as a two-alternative forced choice task with well-specified (i.e., non-probabilistic or ambiguous) monetary rewards and time delays stated as intervals. To ensure a reproducible and unbiased search, we restricted our search to two widely accepted electronic databases: PubMed and the Web of Science Core Collection. Here we deviated from our prespecified protocol as we had registered to search three databases—Scopus, PubMed, and the Web of Science Core Collection—but due to a mistake during the search we had exported only the first ten search results from Scopus which were all found illegible or being duplicates. We used a comprehensive search string that included the concepts of intertemporal choice, delay discounting, temporal discounting, and intertemporal decisions, applying appropriate wild cards and adapting the search string to each database (see Tab. 1). When possible, the search command included a filter for human subjects and original articles. This initial search conducted on 2024/29/02 yielded $4,302$ results (excluding duplicates).

Table 1: Search commands used in each of the databases.

Database	Search string / command line
PubMed	("delay discount*"[Title/Abstract] OR "temporal discount*"[Title/Abstract] OR "intertemporal choice*"[Title/Abstract] OR "intertemporal decision*"[Title/Abstract]) AND "human*"[MeSH Terms]
Web of Science	TS=("delay discount*" OR "temporal discount*" OR "intertemporal choice*" OR "intertemporal decision*") AND DT=(Article)

We then applied a series of prespecified exclusion criteria to filter out studies that did not meet our eligibility criteria. We excluded studies that did not meet our definition of an intertemporal choice task, were not written in English, were not available in full-text format, were not published in a peer-reviewed journal, or whose analyses were not based on primary data. Additionally, we excluded studies conducted in non-human subjects, those that used a non-computerized procedure (which would preclude the collection of response-time data), and those conducted solely in populations with neurological abnormalities or psychiatric disorders (although we did include control groups from such studies if they were included alongside a clinical group). After applying these exclusion criteria, we excluded $1,682$ studies at the abstract screening stage and 911 studies at the full-text stage, leaving $1,709$ candidate publications that met our eligibility criteria and proceeded to the next stage of data collection.

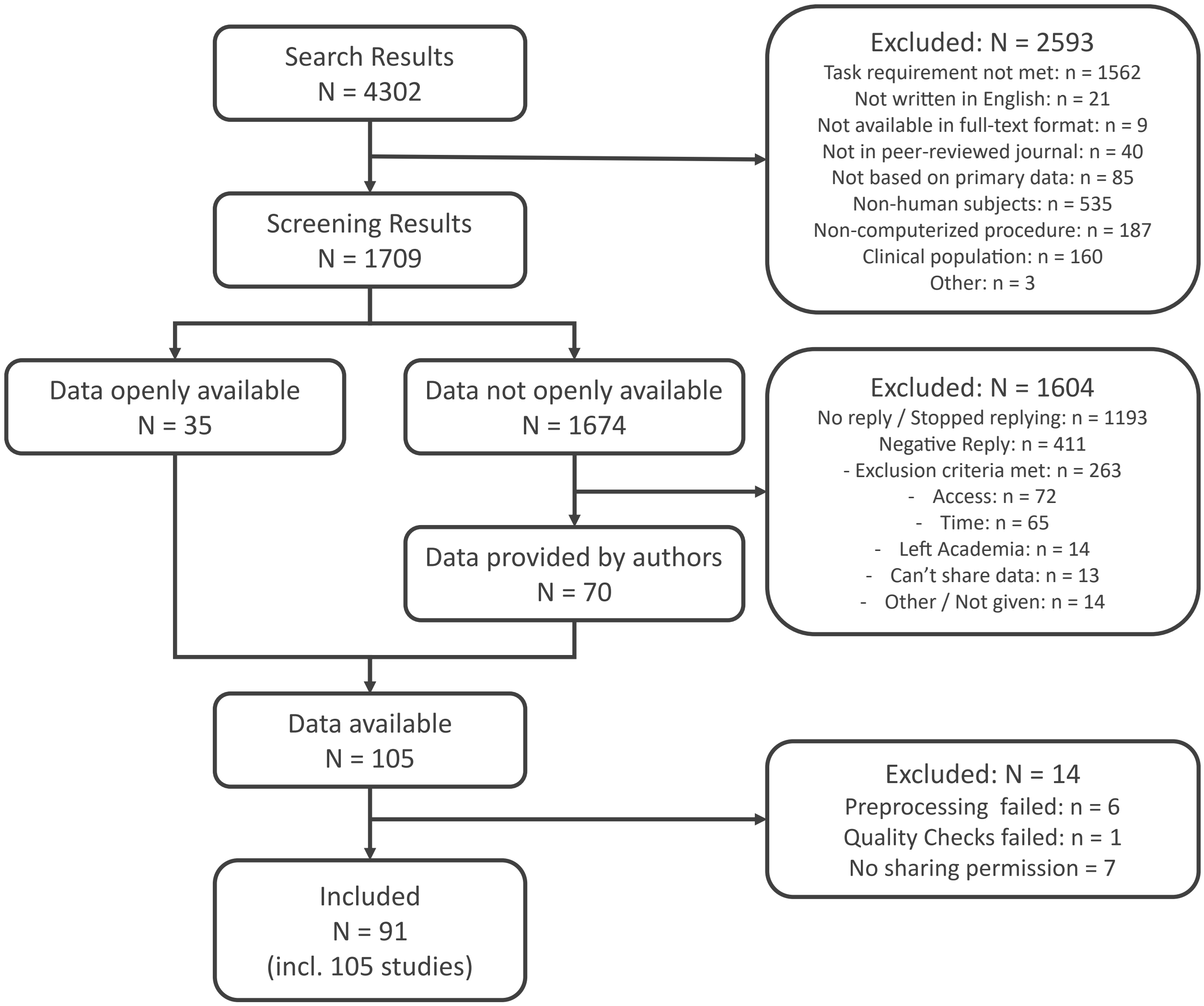

Figure 1: Systematic search and data collection process.

Please note that multiple exclusion criteria may have applied to the same publication.

2.2 Data Collection & Data Processing

To collect the eligible datasets, we employed a two-pronged approach. First, we identified and accessed associated open data repositories that provided all data of interest for 35 publications, extracting and processing the data of interest (as described in the Data Record section) with the aid of the accompanying publication and any publicly available information for understanding the published data. Second, we contacted the corresponding author(s) of the remaining publications with formal data requests, sending out a total of $1,674$ requests. Initially, we asked authors to submit the data of interest in a specific format, extracted and processed according to our requirements. However, to maximize data retrieval, we also accepted unprocessed data from authors, provided they supplied the necessary information to enable us to understand and work with the data. In such cases, we extracted and processed the data of interest ourselves.

Overall, we collected and processed 112 datasets from 98 publications. In a last step, we contacted all corresponding authors asking for permission to publish their dataset(s) within this compilation under a CC BY-NC-SA license. In 91 cases the authors agreed to this, and hence our compilation features 105 datasets from 91 publications (see Tab. 2 in the Data Input section).

2.3 Input Data

Table 2 provides an overview of the publications associated with the eligible datasets included in the compilation

Table 2: Overview of the publications associated with the eligible datasets included in the compilation

No.	Publication	Data Source	Incl. Studies
1	Alonso-Díaz *et al.*[34]	Personal correspondence	1
2	Alvarez *et al.*[35]	Personal correspondence	1
3	Amasino *et al.*[13]	https://osf.io/2p3dj	1
4	Andersen *et al.*[36]	Personal correspondence	1
5	Armstrong & Hoge[37]	Personal correspondence	1
6	Bahrami & Borhani[38]	Personal correspondence	1
7	Becker *et al.*[39]	Personal correspondence	1, 2, 3
8	Berenson *et al.*[40]	Personal correspondence	1
9	Bixter & Luhmann[41]	Personal correspondence	1, 2
10	Bixter *et al.*[42]	Personal correspondence	2
11	Bixter & Rogers[43]	Personal correspondence	1
12	Bruder *et al.*[44]	https://osf.io/xkp7c	1
13	Bulley *et al.*[45]	https://osf.io/n8t5e/	1, 2
14	Calluso *et al.*[46]	http://dx.doi.org/10.6084/m9.figshare.1246203	1
15	Calluso *et al.*[47]	https://figshare.com/s/69e337063503511533dc	1
16	Calluso *et al.*[48]	https://data.mendeley.com/datasets/d2g69jd2pb/1	1
17	Cao *et al.*[49]	https://osf.io/86ztd/	1, 2
18	Castrellon *et al.*[50]	https://osf.io/6p4rk/	1
19	Chiong *et al.*[51]	Personal correspondence	1
20	Civai *et al.*[52]	Personal correspondence	1
21	Croote *et al.*[53]	Personal correspondence	1
22	Daood *et al.*[54]	Personal correspondence	1
23	Demurie *et al.*[55]	Personal correspondence	1
24	Demurie *et al.*[56]	Personal correspondence	1
25	Demurie *et al.*[57]	Personal correspondence	1
26	Dshemuchadse *et al.*[58]	https://osf.io/3w6cr	1
27	Escobar *et al.*[59]	Personal correspondence	1
28	Faulkner *et al.*[60]	Personal correspondence	1
29	Fletcher *et al.*[61]	Personal correspondence	1
30	Fusco *et al.*[62]	https://osf.io/5t6vz/	1
31	Gassen *et al.*[63]	Personal correspondence	1
32	Gluth *et al.*[64]	Personal correspondence	1, 2

33	Hare *et al.*[65]	Personal correspondence	1
34	Hartmann *et al.*[66]	Personal correspondence	1
35	Herting *et al.*[67]	Personal correspondence	1
36	Ikink *et al.*[68]	https://osf.io/g2yf7/	1
37	Jiang & Dai[69]	https://osf.io/at53h/	1, 2a, 2b
38	Jones *et al.*[70]	Personal correspondence	1
39	Kable *et al.*[71]	https://openneuro.org/datasets/ds002843/versions/1.0.0	1
40	Keidel *et al.*[72]	Personal correspondence	1
41	Keidel *et al.*[73]	https://osf.io/td5gf	1
42	Knauth & Peters[74]	https://osf.io/dtwg3	1
43	Konstantinidis *et al.*[75]	Personal correspondence	1
44	Kräplin *et al.*[76]	Personal correspondence	1
45	Kräplin *et al.*[77]	Personal correspondence	1
46	Kräplin *et al.*[78]	Personal correspondence	1
47	Kräplin *et al.*[79]	Personal correspondence	1
48	Kräplin *et al.*[80]	Personal correspondence	1
49	Lange & Eggert[81]	Personal correspondence	1
50	Lempert *et al.*[82]	Personal correspondence	1
51	Lempert & Phelps[8]	Personal correspondence	1
52	Lempert *et al.*[83]	Personal correspondence	1, 2, 3, 4
53	Lempert *et al.*[84]	Personal correspondence	1
54	Linhartová *et al.*[85]	Personal correspondence	1
55	Liu *et al.*[86]	https://osf.io/xtbjk/	1, 2
56	Ljusic *et al.*[87]	Personal correspondence	1
57	Lukinova & Erlich[88]	Personal correspondence	1
58	Mathar *et al.*[89]	https://osf.io/p78wc/	1
59	Mathar *et al.*[90]	https://osf.io/t5zem/	1
60	Ortner *et al.*[91]	Personal correspondence	1
61	O'Hora *et al.*[92]	Personal correspondence	1
62	Reppert *et al.*[93]	Personal correspondence	1
63	Robinson *et al.*[94]	Personal correspondence	1
64	Rodriguez-Moreno *et al.*[95]	Personal correspondence	1
65	Scherbaum *et al.*[96]	Personal correspondence	1
66	Scherbaum *et al.*[97]	Personal correspondence	1
67	Scherbaum *et al.*[98]	Personal correspondence	1
68	Scherbaum *et al.*[99]	Personal correspondence	1
69	Schoemann *et al.*[100]	https://osf.io/3w6cr/	1
70	Schüller *et al.*[101]	https://osf.io/nw9pc	1, 2
71	Schwenke *et al.*[102]	https://osf.io/zq8y2/	1, 2
72	Soutschek *et al.*[103]	Personal correspondence	1
73	Soutschek *et al.*[104]	https://osf.io/uvgdw/	3
74	Soutschek & Tobler[105]	https://osf.io/n7uyz/	1
75	Soutschek *et al.*[106]	https://osf.io/m57yg/	1
76	Soutschek *et al.*[107]	Personal correspondence	1
77	Stevens[108]	https://datadryad.org/dataset/doi:10.5061/dryad.qv0sk	1
78	Thome *et al.*[109]	https://github.com/GKoppe/data_code_repository_gradedDiscounting/blob/main/upload_data_and_code.zip	1
79	Thrailkill *et al.*[110]	Personal correspondence	1
80	Thrailkill *et al.*[111]	Personal correspondence	1

81	Thrailkill *et al.*[112]	Personal correspondence	1
82	Wagner *et al.*[113]	Personal correspondence	1
83	de Water *et al.*[114]	Personal correspondence	1
84	Weidacker *et al.*[115]	Personal correspondence	1
85	Yang *et al.*[116]	https://osf.io/prcbm/	1
86	Zgonnikov *et al.*[117]	https://osf.io/qn2w6/	1
87	Zhang *et al.*[118]	https://osf.io/fd3pz/?view_only=77472ab47d2c4acb9e2de3ede4d5f506	1
88	Zhao *et al.*[119]	https://osf.io/skrh5	1
89	Zhou *et al.*[120]	Personal correspondence	1
90	Zhou *et al.*[121]	https://osf.io/8w6eq/	1
91	Zilker & Pachur[122]	https://osf.io/bj2tv	1

3 Data Record

The compilation is hosted on the Open Science Framework (OSF)—https://osf.io/mxucn/—under a CC BY-NC-SA license. Each dataset in the compilation consists of two files: a data file in .csv-format and a README file in .txt-format; the information from the README files is also assembled in a summary table in .xlsx-format.

The data files contain the following fields:

- ***subj_idx***: The subject index or identifier
- ***ss_value***: The reward value of the smaller, sooner option
- ***ss_time***: The delay of the smaller, sooner option
- ***ll_value***: The reward value of the larger, later option
- ***ll_time***: The delay of the larger, later option
- ***rt***: The response time of the decision in seconds
- ***choice***: The chosen option (0 = SS chosen, 1 = LL chosen)

Additionally, data files may contain the following fields:

- ***subset***: A variable used to map data to specific entries in the dataset (i.e., in cases where parts of the dataset differ in key experimental variables)
- ***session***: A session index or identifier for the session in which the data was collected (i.e., in cases where subjects completed multiple sessions)
- ***trial_idx***: The trial index, indicating the order in which trials were presented (*NA* indicates unknown order)
- ***subj_excl*** & ***subj_excl_ind***: Indicators of whether a subject should be excluded based on our exclusion criteria, and the reason for exclusion
- ***trial_excl*** & ***trial_excl_ind***: Indicators of whether a trial should be excluded based on our exclusion criteria, and the reason for exclusion
- ***additional_conditions***: Any special conditions or characteristics of the subjects that are not grounds for exclusion
- ***age***: The age of the subject

The README files contain the following fields:

- ***DOI***: DOI of the associated publication
- ***Data Location***: Link to data repository, if the original data is openly available
- ***Country***: The country in which the experiment was conducted or from which the participants were recruited in the case of online studies
- ***Currency***: The currency in which the monetary reward values were presented
- ***Time unit***: The unit in which delays were given
- ***Procedure***: The method of the trial construction (e.g., Titration Procedure, Full Cross, Fixed Set, Random Set, Kirby Questionnaire, etc.)
- ***Incentivization***: The method of choice incentivization (e.g., Real Choices, Potentially Real, Hypothetical, etc.)
- ***Presentation of Attributes***: The method of attribute presentation in the trial (Simultaneous or Sequential)
- ***Additional Methods***: A description of any additional methods used in the study (e.g., fMRI, EEG, Mouse-tracking, etc.)
- ***Additional Interventions***: A description of any additional interventions used in the study (e.g., Episodic Future Thinking, Explicit Zero Framing, etc.)
- ***Fixed Attributes***: Attribute(s) fixed for the duration of the entire study
- ***Online Study***: Whether the study was conducted online (Yes/No)
- ***Time Pressure***: Whether there was a response deadline (Yes/No) and if yes, how long
- ***Exclusion criteria subjects***: A description of the exclusion criteria applied to the subjects
- ***Exclusion criteria trials***: A description of the exclusion criteria applied to the trials
- ***RT in full seconds***: Whether the response times were recorded in full seconds (Yes/No)
- ***RT data analyzed***: Whether response time data have been analyzed in the original publication (Yes/No)
- ***Comments***: Any additional comments or notes about the study

4 Technical Validation

To ensure the technical quality of the datasets in our compilation, we performed several checks and analyses with regard to subject and trial numbers, missing values, stimulus information, choice, and response times.

We compared the stated number of subjects and trials in the publications to the actual numbers present in the datasets. We identified deviations in the number of subjects and in the number of trials in 17 and 13 datasets, respectively. We logged these in the README files. We checked the number of missing values in all fields and, where possible, compared them to the information in the publication. We identified no deviations for this.

We visually inspected the distribution of the stimulus information (i.e., *ss_value* < *ll_value*; *ss_time* < *ll_time*) to identify values that were obviously outside of the expected pattern. In these cases, we contacted the authors to verify or correct the data. In one case the discrepancy could not be resolved, and the trials in question where excluded following the authors recommendation.

To check the plausibility of the choice coding, we performed logistic regression analyses. Specifically, we regressed the dichotomous choice on the stimulus information and checked if the probability of choosing the larger, later option

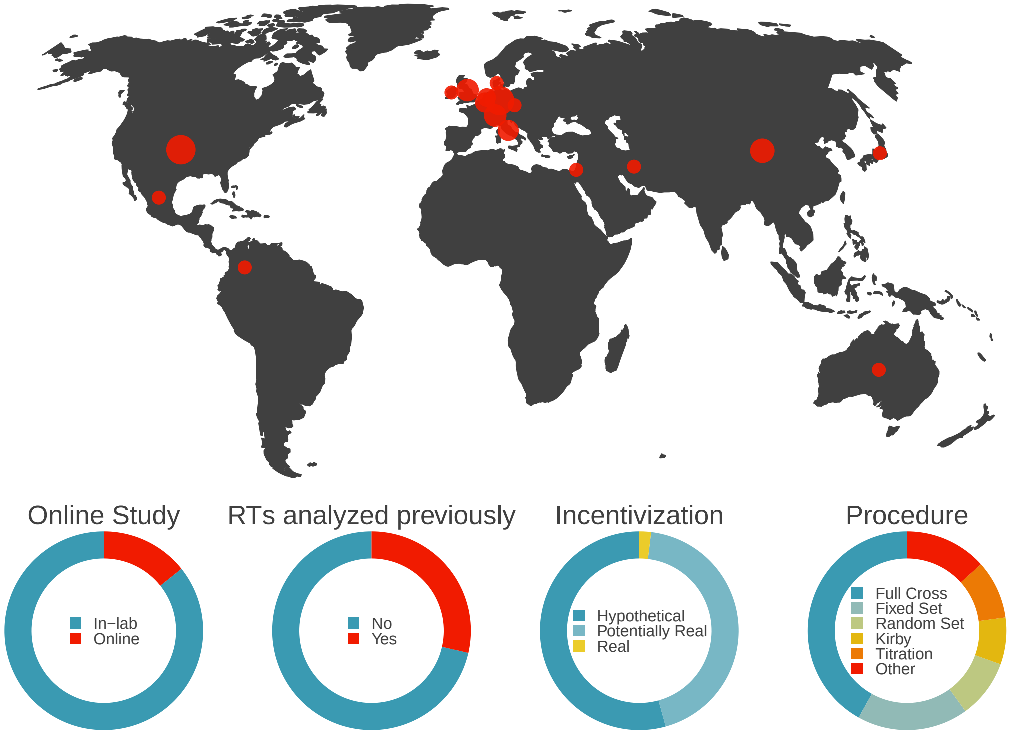

Figure 2: Overview of datasets in the compilation. Worldmap (top) shows the geographical origin of the datasets. Donut charts (bottom) show the proportion of selected study characteristics.

increased with increasing *ll_value*, decreasing *ss_value*, decreasing *ll_time*, and increasing *ss_time*. If half or more of the predictors did not show the expected effect, we visually inspected the choice distribution across as well as for individual subjects. If this did not resolve the issue, we contacted the authors. In one case, the discrepancy could not be resolved, and the study in question was excluded.

To check the plausibility of the RTs, we checked for implausibly fast or slow response times ($M_{rt} > 10$, no negative RTs, more than 10% of RTs below 200 ms, more than 10% of RTs above 20 s if no time pressure was applied, and no RT exceeding the respective response deadline, if time pressure was applied). Most often this was due to the RTs being indicated in milliseconds (ms) instead of seconds (s). However, in two instances, this was not the case. For these, we contacted the authors to resolve the issue, which we were able to do in all cases. As the focus of this compilation lies on RT data, we additionally evaluated the RT distributions per subject based on skewness and bi-modality index and we expected right-skewed, uni-modal RT distributions in more than 80% of the subjects. We identified no study violating this expectation.

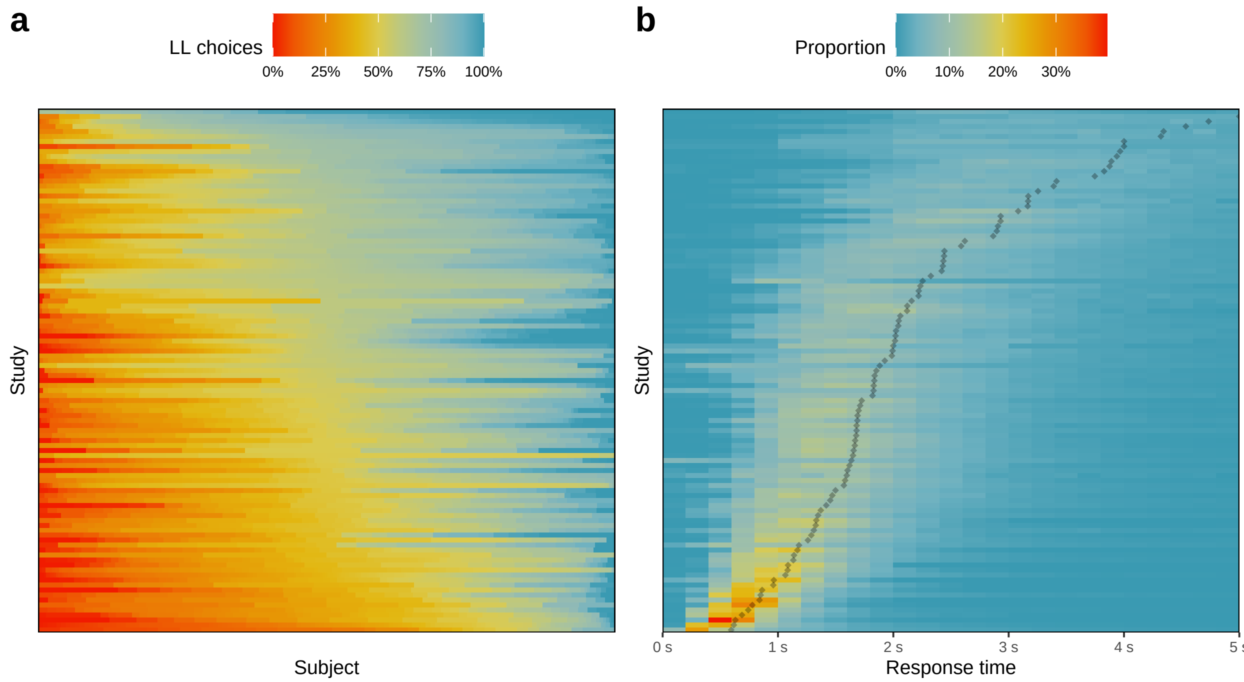

Figure 3: Choice and RT distribution per dataset. (a) Proportion of LL choices for each subject with datasets ordered by the overall proportion of LL choices. (b) Proportion of RTs for each RT bin across all subjects with datasets ordered by the median RT (indicated by the black diamonds).

5 Code Availability

The code to assemble the compilation from the processed datasets is included in the database (https://osf.io/mxucn/). The code for processing the raw datasets is not provided, as a) we may have received the data already processed and therefore do not have the respective code, and b) we do not publish the raw datasets. Code to reproduce the tables, figures, and quality checks in this article is included in the repository for this Data Descriptor (https://osf.io/3wsae/).

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Hannah Pongratz: Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Visualization, Writing - Review & Editing; **Martin Schoemann**: Conceptualization, Methodology, Resources, Visualization, Supervision, Project administration, Writing - Original Draft, Writing - Review & Editing.

The authors have no competing interests to declare.

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