Advancing Perspectivist Ground Truthing with Social Science

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# Introduction

AI systems run on data. Data are used to ‘train’ models - imperfect, simplified mathematical or computational representations of a phenomenon or process in the real world [[1]](#footnote-20). Where an AI system is a complete application with integrated components e.g. an interface, programmatic logic, and one or more models aimed at performing tasks typically requiring human intelligence, the models themselves are embedded components that take inputs (e.g. media like text, images, audio, or data) and produce outputs (e.g. classifications, predictions or some form of decision). The behavior of models, i.e. how they respond to a given input, is determined by their parameters - internal settings or values. Algorithms - step by step instructions, executed in order - are used to estimate model parameters from the ‘training’ data. As models used in AI systems are designed to perform tasks, their performance is evaluated empirically by comparing their outputs to a reference. This reference is often a second form of data, referred to as the ‘ground truth’, ‘gold standard’, or simply ‘annotations’, which represents the ideal output of the system.

Whether used as part of the development of an AI system, or to evaluate it, the quality of these two forms of data determines the quality of the system. As parameters are estimated from the training data, such that observable patterns recognized in the data affect internal model values or settings, imperfections, inaccuracies, biases etc. in the data are reflected in the parameters of the resulting model. As models are evaluated by comparing their outputs to reference data, such that ‘better’ models are those whose outputs most closely resemble the reference data, imperfections in the reference are reflected in the models preferred. Thus, the quality of the data used for training and reference represents the upper boundary of potential performance of AI systems when deployed: the best possible performance directly corresponds to the degree to which training and reference data represent the phenomenon of interest to the system when deployed.

Training data is often a form of media - text, audio, images, or video - whereas reference data very often contains aggregated input from humans. This implies that a phenomenon of interest is set as a target, and human judges are given a task that produces data from their input. Common scenarios include human judges annotating, labeling, or rating a) individual pieces of content of the same form as the training data, or b) generated system outputs. Multiple ratings per piece of content are collected and usually aggregated, forming a singular ‘ground truth’ for the aspect of the content being labelled or rated.

Although far more emphasis is placed on whether models achieve state of the art ‘performance’ or efficiency (Birhane et al., 2022), scholars over the past decade have attempted to draw attention to a lack of sophistication in how training and reference data are selected and evaluated. It has further been argued that a focus on improving the data, will result in bigger gains than a focus on improving the model[[2]](#footnote-21), and that data set size can not compensate for the shortcomings in data set quality (Hullman et al., 2022). Issues include 1) representational biases in the content sampled for inclusion in training/evaluation datasets (Hullman et al., 2022), 2) measurement biases in the annotations collected (Beck et al., 2022; Hullman et al., 2022; Jacobs & Wallach, 2021), 3) a fallacious assumption of a single canonical ‘ground-truth’ (Aroyo & Welty, 2015; Cabitza et al., 2023), and 4) poor reporting of necessary information regarding the annotation-collection process (Geiger et al., 2021; Hullman et al., 2022).

An additional consideration that receives little attention is the number of annotations to gather, where fields that focus on gathering data from humans also have a strong emphasis on *a-priori* calculations of target sample sizes. These considerations are absent in computational fields which appear to favor differing rules of thumb: e.g. in a well-cited textbook, Pustejovsky & Stubbs (2013) suggest to “have your corpus annotated by at least two people (more is preferable, but not always practical)”, whereas Artstein & Poesio (2008) suggest that “measuring reliability with only two coders is seldom enough, except for small-scale studies”. On the one hand, corpora tend to be very large, and resources are finite. However, rules of thumb lack clear substantiation, in light of the both the phenomenon being grounded and the nature of the media in which it is grounded. In other words, more variance is expected in annotation targets to the degree they are subjective e.g. whether or not a piece of text represents hate speech (Beck et al., 2022), and more variance is expected in content to the degree to which it is ambiguous (Sandri et al., 2023).

Scholars further note a gap between practices in Machine Learning fields, and knowledge from the social sciences which could address these issues, but has yet to be broadly applied. One reason for this gap may be ML researchers prefer to work on building systems and evaluating their performance rather than executing ground-truthing projects (Sambasivan et al., 2021). Another may be a lack of focus on these topics in textbooks, and thus in education more broadly (first geiger paper I think). A third may be that the social and computational sciences have conceptually different focci: the computational sciences focus on the statistical model the system with substantially less emphasis on the content, whereas the social sciences treat the statistical model as a means to better understanding the relationships in the content (Liem et al., 2018). A further more practical complication is that work on these topics and potential solutions lacks a central academic ‘home’: where psychology and economics have psychometrics and econometrics respectively, and where software engineering has software testing, the study of ground-truthing lacks a central banner under which academic work can accumulate.

## Present Work

This thesis incorporates the aforementioned shortcomings into a singular framework, guided by best practices in the social sciences. Thus our primary contribution is a worked example of a ground-truthing project which involves the collection of human annotations, and that attempts the application of practices from the social science for each of the issues above.

Specifically:

* We attempt to mitigate representation biases in the content we select for annotation by using a stratified sampling strategy.
* We attempt to mitigate measurement biases by treating the target measurement as a latent variable, and the survey we used to gather annotations as an instrument. We build on work that validated a questionnaire for measuring constructs, and estimating its reliability and structural validity when used for annotations.
* We account for the potential of multiple perspectives in our dataset by recruiting participants from relevant subgroups in a single target population.
* We report the details of the annotation collection process, and share the disaggregated dataset of the annotations
* We further show how to estimate the number of annotators

We demonstrate the potential of this framework by grounding a complex phenomenon (a 10-dimensional construct, Personal Values) in ambiguous text (song lyrics). We further show an

When sampling content to include in training/test datasets, samples for the training/test sets will ideally be drawn from the same distribution as the content in which they will eventually be deployed. *Representation bias* in content selected for training and/or evaluation datasets refers to the degree to which relevant distributions in data used to train and/or evaluate systems resembles the distribution in the environment to which it will be deployed (Hullman et al., 2022).

Measurement bias in the annotations collected from humans may also bias

Perspectivism

Reporting

We add: a priori rating number estimation

And although imperfect as leaderboard scores can be gamed, and do not perfectly represent the deployment environment, the typical leaderboard approach has shown evidence that progress can be made towards a target. This thesis thus represents an attempt to define the target better.

# ML/AI relies on reference data from human annotations

Aroyo & Welty (2015)

* In order to evaluate ML / AI systems, we compare the output of these systems to reference data.
* One method for creating reference data is the collection of human annotations.
* This method typically assumes that, for every piece of content being annotated, there is a single canonical truth
* quality of annotations is assessed using inter-annotator agreement, where more agreement = better annotations

Cabitza et al. (2023): “data annotation is the practice of labeling a set of digital representations of objects.”

according to Muller et al., 2012 it has three components

* data collection: the labeling scheme
* data annotation: the actual labeling by experts or crowd workers
* data aggregation: producing a single or a single set of labels from the multiple labels collected

Geiger et al. (2021): ML uses human annotations very often

* 200 randomly sampled ML papers from 3 domains:
  + Social Sciences & Humanities
  + Life & Biomedical Sciences
  + Physical & Environmental Sciences
* Out of 141 classification tasks, 103 (73.05%) used human labels
* Out of 103 human labels, 58 (56.31%) used only external labels

i.e. ML re-uses external labels

## Issues using human annotations in ML

A number of works have shown issues with annotations in ML

Hullman et al. (2022) compare claims that ML is facing a reproducibility crisis to the crisis in psychology. Among the issues they note relate to benchmark datasets, which researchers often re-use as they publish on standardized benchmarks, and because they are cost prohibitive to collect.

Another may be that the skills are not being taught: [geiger, first paper, show lack of reporting in ML textbooks on ground truthing]

A number of papers have drawn from the social sciences to synthesize knowledge on how best to gather annotations.

### ML treats all annotation variance as noise rather than signal

disagreement is common

reviewed in Cabitza et al. (2023): -social media content: Chandrasekharan 2017 -medical cases: Cabitza 2019 -various NLP tasks Aroyo & Welty (2015)

disagreement is often removed

* adjusting annotator training and instruction
* adjusting annotations via discussion post-collection
* majority voting, post-hoc without annotators

Beyond errors in judgment are questions about the target for the annotations. For at least some phenomena, the assumption that there is a single ground-truth to approximate with annotations doesn’t hold.

Aroyo & Welty (2015)

7 ‘myths’ of human annotation:

* there is one truth
* disagreement is bad
* detailed guidelines help
* experts are better
* one annotator is enough
* all items are created equal
* once done, forever valid

For myths 1 and 2:

* list examples from NLP where the disagreement from annotators is sensible
* they argue that the assumptions of a single ground truth, and that disagreement is indicative of poor annotations are both false.

for myth 6: disagreement indicates that the media being rated is ambiguous.

#### annotations aim to measure a latent variable

Jacobs & Wallach (2021) there is a ‘measurement error model’ (taken from econ) that links the unobservable latent variable, and observable properties. in annotations this is via individual observations

although paper focuses on attempts at measuring constructs (risk of recidivism, teacher effectiveness, patient benefit) they also show that even ‘representational measurements’ like height, are essentially a latent variable

Aroyo & Welty (2015) operationalize ‘crowd truth’ with an illustration where the ‘gold standard’ is the probability that a sentence contains an element, based on the probability that an annotator annotated that sentence with that element.

* i.e. the label isn’t represented as ‘present’ or ‘not present’, but as a probablility
* thus the ‘crowd truth’ attempts to capture the ‘range of reasonable interpretations’

Beck et al. (2022): we should expect more variance to the degree that tasks measure opinion show work on an intuitively perspective-based use-case: hate speech

### Human annotations aren’t always accurate

Griffin & Brenner (2004) review errors and biases in human judgements[[3]](#footnote-26)

* over/under prediction: confidence score is higher/lower than accuracy
* over/under extremity: confidence is more extreme at ends

also reviews possible reasons:

* optimistic overconfidence
* confirmation bias
* case-based judgment
* ecological probability
* error model (psychometric model)

### Inadequate reporting

Geiger et al. (2021) ML science studies inadequately report ‘ground truth’

Hullman et al. (2022) thus we cannot know what data generating process the resulting model represents

[perhaps cat image parable here?]

### sampling and measurement biases

Hullman et al. (2022)

With regards to reference data:

* representation bias / non-representative samples
* measurement bias / unvalidated measurement instruments
* underspecification of portions of input space in training data
* transformation of data to optimize for ‘accuracy’
* lack of or poor dataset documentation

In other words, optimizing for predictive accuracy using very large datasets does not ‘absolve’ researchers from having to consider the data generating process. They note benefits that both machine learning and psychology could gain by borrowing methods from each other, but note the danger if these are misused. For the benefit of machine learning, there are lessons to be learned from social science, and the replication crisis. Among them are 1) collecting samples whose test/evaluation set distributions are drawn from the same deployment distribution, and 2) using valid measurement instruments.

### ML doesn’t treat annotation generating process as an instrument

Beck et al. (2022)

* annotation collection requires design thinking
  + Task Structure: specific wording and response options, including debates over the inclusion of “I don’t Know” option
  + Order Effects: specific judgements are affected by previous perceptions
  + Annotator Effects: backgrounds, opinions, experiences of respondents affect responses

Jacobs & Wallach (2021)

* reliability: do similar inputs to a measurement model present similar outputs?

test-retest: are measurements of an unobservable latent construct taken at different times via a measurement model similar, assuming the construct hasn’t changed?

* validity: is it ‘right’?

no single test for validity on purpose, because it requires thinking. do our measurements:

* face validity: look plausible/ sensible?
* content validity: capture the construct?
  + structural validity: show the inter-correlations we expect?
  + substantive validity: capture only observable properties thought to be related to the construct?
* convergent validity: show correlations with other validated methods?
* discriminant validity: show correlations with other construct/properties thought not to be related to the construct?
* predictive validity: show correlations with constructs/properties thought to be related, but not in the operationalization?
* hypothesis validity: shed light on relevant hypotheses about the construct being measured?
* consequential validity: allow for the consequences obtained from the measurement model to be assessed?

### ML ignores perspectives of annotators

Cabitza et al. (2023): whether the target of the annotation is a subjective phenomenon or not, disagreement is always irreducible. Yet ML typically assumes there is a single ‘ground truth’, and its best indicator is inter-annotator agreement. But taking the perspectives of the annotators into account, both in the data annotation but also the modelling phase of ML projects has recently been shown to benefit ML modelling in a number of contexts.

weak perspectivist approach: taking perspectives into account while designing and collecting annotations, but ultimately reducing annotations to a single label or rating.

strong perspectivist approach: taking perspectives into account for ground truthing and modelling phases.

benefits of this approach:

* is congruent with the reality of collecting annotations
* includes the signal in the variance of labels or ratings
* avoids majority group perspective appearing to be ‘objective’
* allows for the modelling of human errors and variances
* allows for uncertain, fuzzy, or soft model development
* more complete report of the data generating process, as it also reports uncertainty

downsides:

* multiple raters, and therefore costs/time/rater availability are issues
* need for perspectivist ML approaches
* validation becomes more challenging

recommendations:

* complete labeling schemes, including ‘i don’t know’, ‘none of these’ etc. categories, and the ability to express issues with label set
* enough raters
* heterogenous raters
* adequate reporting:
  + number of raters,
  + rater expertise
  + incentive
  + instructions
  + length of time for labelling
  + inter rater agreement
  + aggregation method
  + confidence

# Tools from Social Science can help

Recent trends—especially in deep learning—prioritize empirical performance over theoretical assumptions about the data generating process. A systematic analysis of highly cited ML works shows that Performance, Generalization, Quantitative evidence, Efficiency, Building on past work, and Novelty are the primary values in ML work Birhane et al. (2022).

Unlike the social sciences (e.g. psychology), ML work ignores attempts to model the process that gives rise to the data, assuming it cannot be learned, and aims instead at predictors that will within estimable error bounds Hullman et al. (2022). This is problematic as this kind of optimization doesn’t resemble real world deployment.

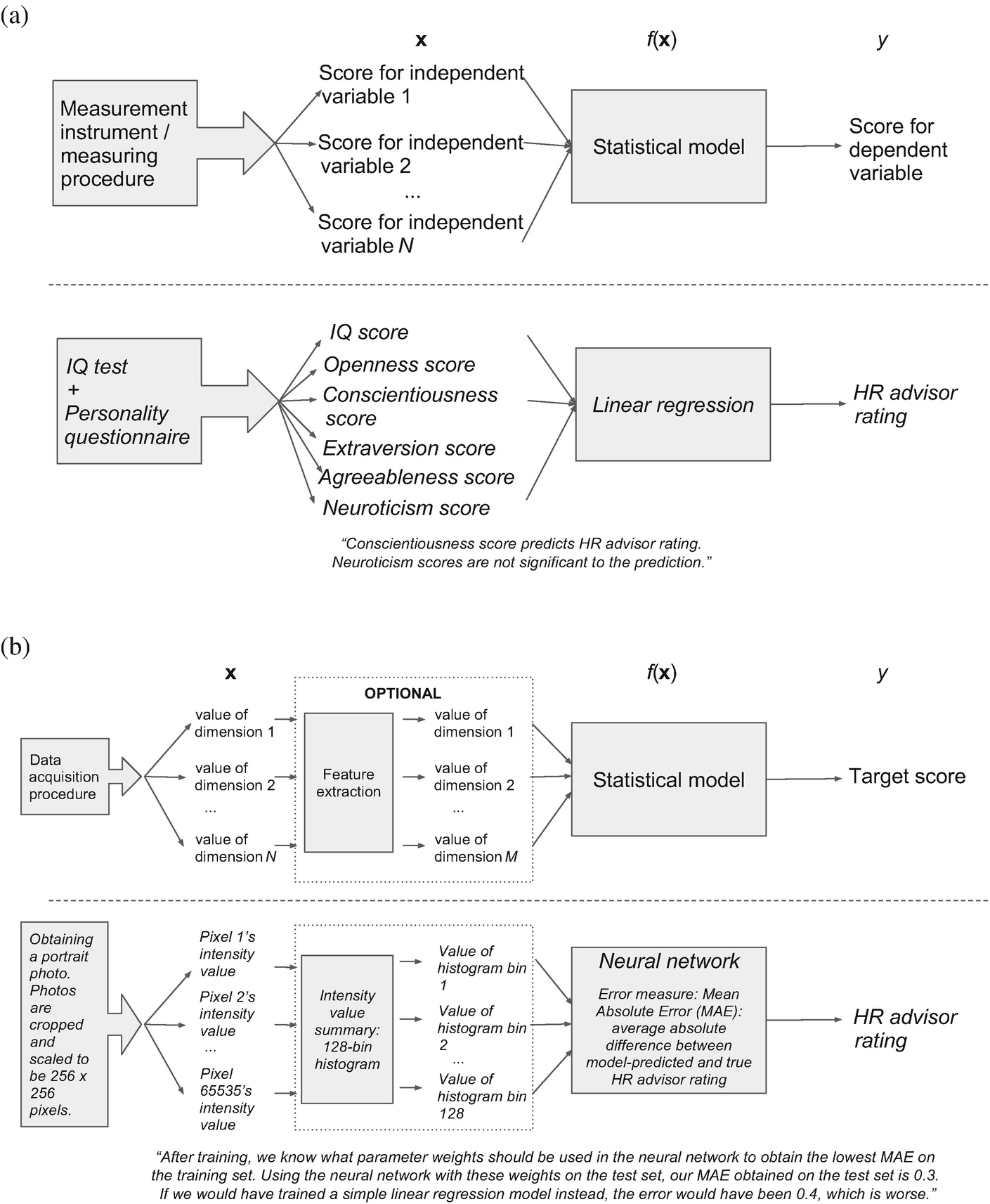
### Social and computational sciences have different focci

social sciences:

* interpretable meaning of x and y
* design is informed by theory

computational sciences:

* learning procedure f(x)

 Fig. 1: Liem et al. (2018)

### Issues with sampling

Solutions to sampling problems can come from sampling theory: Groves et al. (2009)

considerations:

* sampling frame: the elements in from populations that you have access to
* ineligible units: elements in the sampling frame that are not your target
* undercoverage: elements from target population that are not in the frame

solutions:

* stratified sampling

### Issues with instruments

Beck et al. (2022)

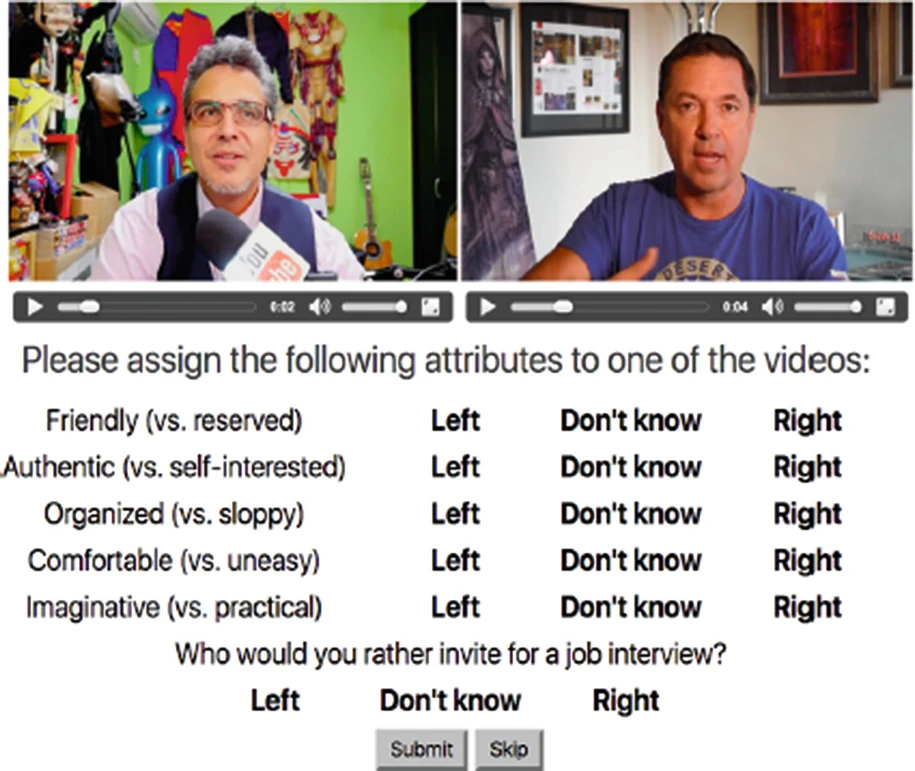
* annotation collection requires design thinking
  + Task Structure: specific wording and response options, including debates over the inclusion of “I don’t Know” option
  + Order Effects: specific judgements are affected by previous perceptions
  + Annotator Effects: backgrounds, opinions, experiences of respondents affect responses

[another ref that describes the target as a latent variable]

### A tale of two studies: the case of personnel selection

Ponce-López et al. (2016)

* efficient way to gather media and annotation data
* BUT no validation of instrument, or ecologically valid media data
* distribution of training /eval data don’t come from the target distribution

 Figure 2: Ponce-López et al. (2016)

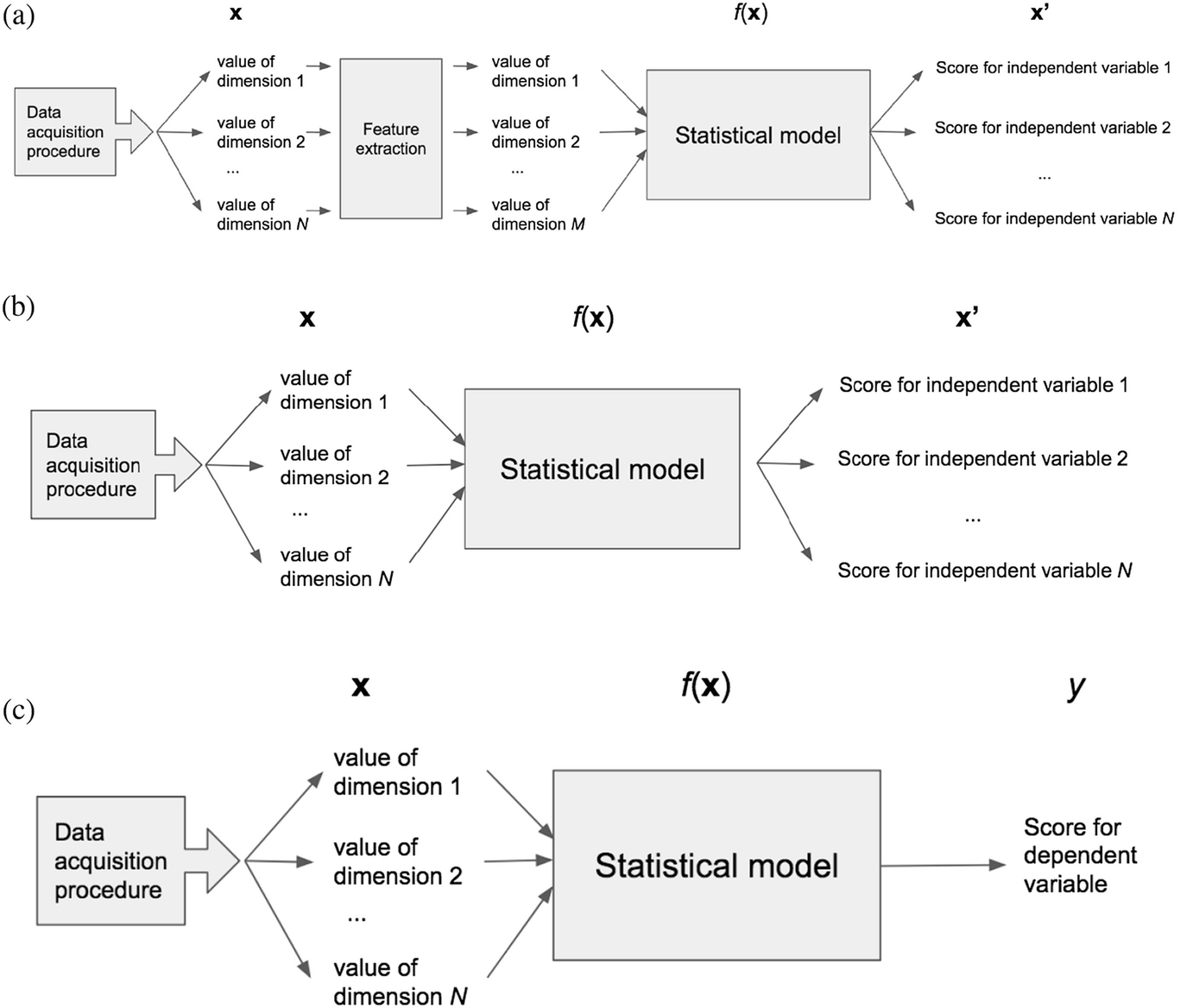
Compared to Koutsoumpis et al. (2024):

* ecological validity: media data was mock asynchronous video interviews
* ecological validity: interview questions designed to activate personality facets
* personality instruments: validated HEXACO scale
* perspectives: self & observer ratings

# Present Work

We incorporate these considerations in the design of our study, and attempt to further the field in the following ways:

* we attempt representative sampling of both media and respondents
* we aim to estimate 10-dimensional psychological construct
* we select media that is ambiguous (i.e. that will result in subjectivity in the ratings) as well as media that we expect not to be ambiguous for comparison
* we estimate a-priori the number of ratings necessary rather than assuming
* we take into account perspectives

case study of this thesis works towards path (b) in Liem et al. (2018) shown in: 

## References

Aroyo, L., & Welty, C. (2015). Truth is a lie: Crowd truth and the seven myths of human annotation. *AI Magazine*, *36*(1), 15–24.

Artstein, R., & Poesio, M. (2008). Inter-coder agreement for computational linguistics. *Computational Linguistics*, *34*(4), 555–596.

Beck, J., Eckman, S., Chew, R., & Kreuter, F. (2022). Improving labeling through social science insights: Results and research agenda. *International Conference on Human-Computer Interaction*, 245–261.

Birhane, A., Kalluri, P., Card, D., Agnew, W., Dotan, R., & Bao, M. (2022). The values encoded in machine learning research. *Proceedings of the 2022 ACM Conference on Fairness, Accountability, and Transparency*, 173–184.

Cabitza, F., Campagner, A., & Basile, V. (2023). Toward a perspectivist turn in ground truthing for predictive computing. *Proceedings of the AAAI Conference on Artificial Intelligence*, *37*, 6860–6868.

Geiger, R. S., Cope, D., Ip, J., Lotosh, M., Shah, A., Weng, J., & Tang, R. (2021). " garbage in, garbage out" revisited: What do machine learning application papers report about human-labeled training data? *arXiv Preprint arXiv:2107.02278*.

Griffin, D., & Brenner, L. (2004). Perspectives on probability judgment calibration. *Blackwell Handbook of Judgment and Decision Making*, *199*, 158–177.

Groves, R. M., Fowler Jr, F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2009). *Survey methodology* (Vol. 561). John Wiley & Sons.

Hullman, J., Kapoor, S., Nanayakkara, P., Gelman, A., & Narayanan, A. (2022). The worst of both worlds: A comparative analysis of errors in learning from data in psychology and machine learning. *Proceedings of the 2022 AAAI/ACM Conference on AI, Ethics, and Society*, 335–348.

Jacobs, A. Z., & Wallach, H. (2021). Measurement and fairness. *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency*, 375–385.

Koutsoumpis, A., Ghassemi, S., Oostrom, J. K., Holtrop, D., Breda, W. van, Zhang, T., & Vries, R. E. de. (2024). Beyond traditional interviews: Psychometric analysis of asynchronous video interviews for personality and interview performance evaluation using machine learning. *Computers in Human Behavior*, *154*, 108128.

Liem, C. C., Langer, M., Demetriou, A., Hiemstra, A. M., Sukma Wicaksana, A., Born, M. P., & König, C. J. (2018). Psychology meets machine learning: Interdisciplinary perspectives on algorithmic job candidate screening. *Explainable and Interpretable Models in Computer Vision and Machine Learning*, 197–253.

Ponce-López, V., Chen, B., Oliu, M., Corneanu, C., Clapés, A., Guyon, I., Baró, X., Escalante, H. J., & Escalera, S. (2016). Chalearn lap 2016: First round challenge on first impressions-dataset and results. *Computer Vision–ECCV 2016 Workshops: Amsterdam, the Netherlands, October 8-10 and 15-16, 2016, Proceedings, Part III 14*, 400–418.

Pustejovsky, J., & Stubbs, A. (2013). *Natural language annotation for machine learning*  (First Edition). O’Reilly Media.

Sambasivan, N., Kapania, S., Highfill, H., Akrong, D., Paritosh, P., & Aroyo, L. M. (2021). “Everyone wants to do the model work, not the data work”: Data cascades in high-stakes AI. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–15.

Sandri, M., Leonardelli, E., Tonelli, S., & Ježek, E. (2023). Why don’t you do it right? Analysing annotators’ disagreement in subjective tasks. *Proceedings of the 17th Conference of the European Chapter of the Association for Computational Linguistics*, 2428–2441.

1. Griffin & Brenner (2004) note that much of this work was about people guessing knowledge from an almanac, and then guessing how accurate they were [↑](#footnote-ref-20)
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