The unpredictability of life outcomes

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NICHD Advisory Council

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social science $\leftrightarrow$ data science

Life trajectory prediction task: Given some data about a person and their environment, how well can we predict their future outcomes?

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- obvious and heretical
- old and new
- scary and exciting

Can an Algorithm Tell When Kids Are in Danger?

Child protective agencies are haunted when they fail to save kids. Pittsburgh officials believe a new data analysis program is helping them make better judgment calls.

By DAN HURLEY JAN. 2, 2018

$$\hat{y} \quad \textit{vs} \quad \hat{\beta}$$

Mullainathan and Spiess (2017)

$$\hat{y} \quad \& \quad \hat{\beta}$$

Mullainathan and Spiess (2017)

Measuring the predictability of life outcomes with a scientific mass collaboration

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Fragile Families

& Child Wellbeing Study

PRINCETON | COLUMBIA

Future of Families

& Child Wellbeing Study

PRINCETON | COLUMBIA

Future of Families
& Child Wellbeing Study

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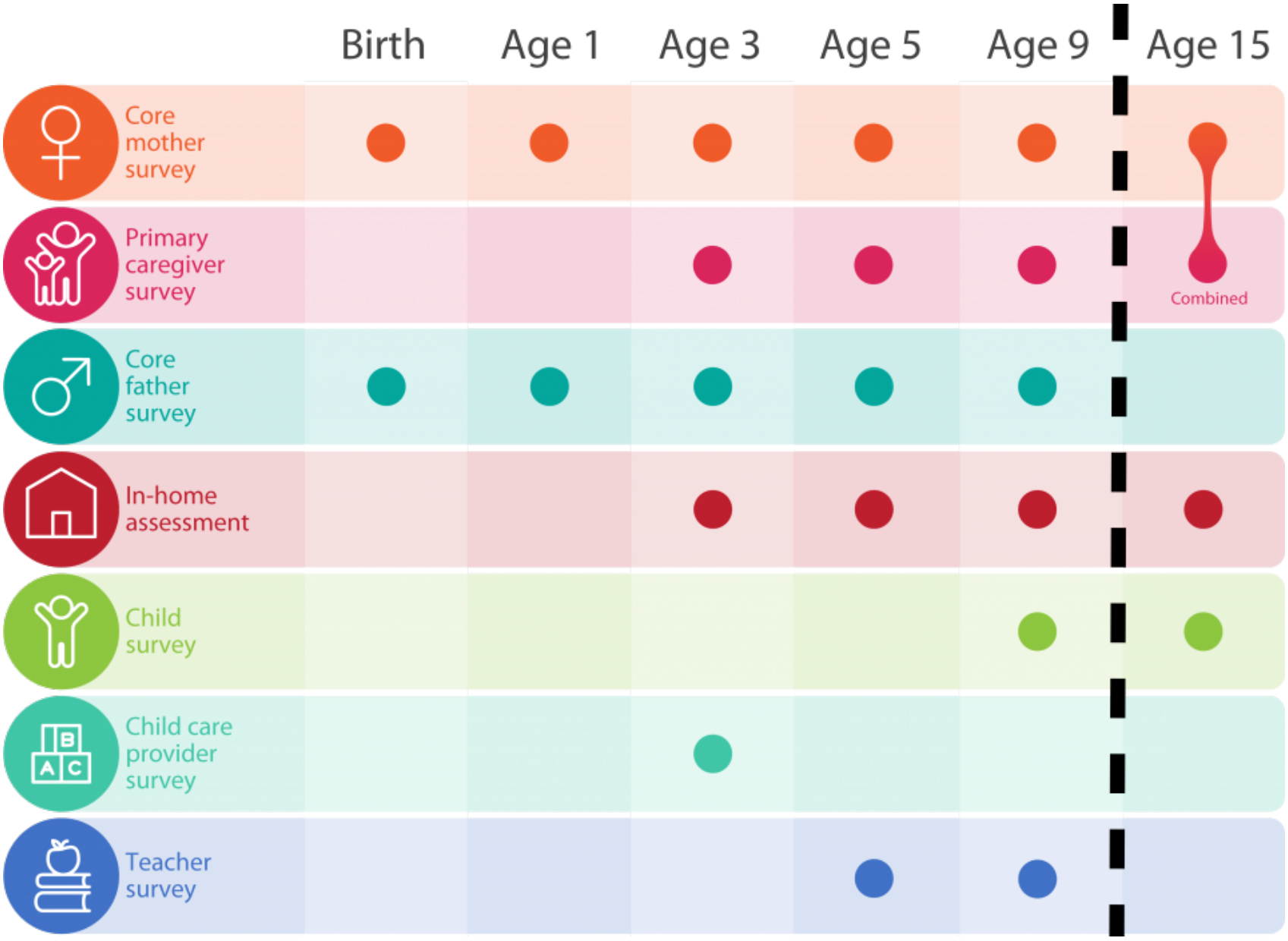
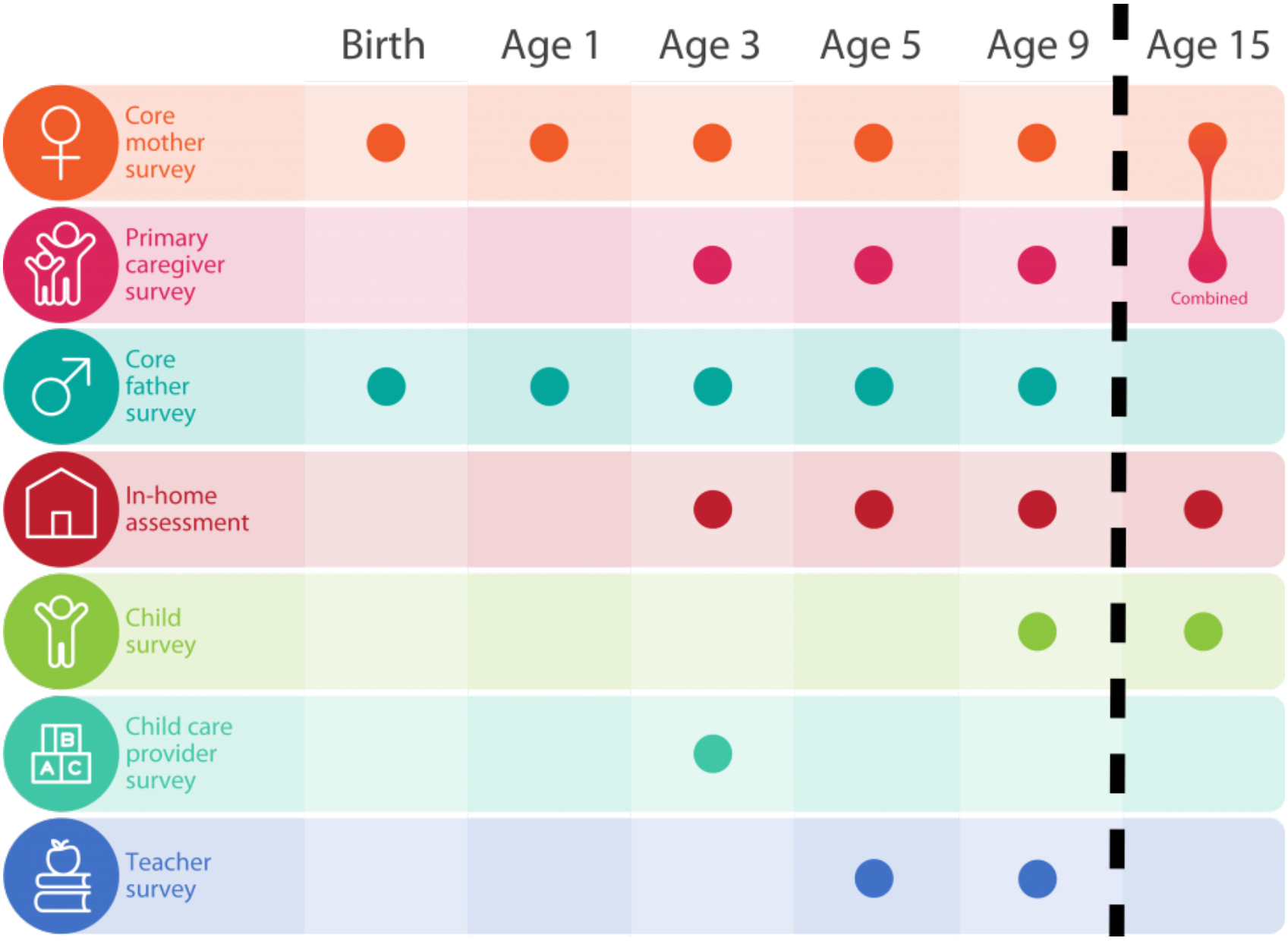
- Thousands of children born in 20 U.S. cities with an over-sample of non-marital births
- Followed from birth
- Already used in more than 1,000 published papers


Birth
Age 1
Age 3
Age 5
Age 9
Age 15
Core mother survey
Primary caregiver survey
Combined
Core father survey
In-home assessment
Child survey
Child care provider survey
Teacher survey

Data module	Child age	Module
Mother	Birth	Child health and development; Mother-father relationships; Fatherhood; Marriage attitudes; Relationship with extended kin; Environmental factors and government programs; Health and health behavior; Demographic characteristics; Education and employment; Income

Data module	Child age	Sections
Mother	Birth	A) Child health and development, B) Father-mother relationships, C) Fatherhood, D) Marriage attitudes, E) Relationship with extended kin, F) Environmental factors and government programs, G) Health and health behavior, H) Demographic characteristics, I) Education and employment, J) Income
Father	Birth	A) Child health and development, B) Father-mother relationships, C) Fatherhood, D) Marriage attitudes, E) Relationship with extended kin, F) Environmental factors and government programs, G) Health and health behavior, H) Demographic characteristics, I) Education and employment, J) Work activities, K) Income
Mother	1	A) Family characteristics, B) Child well-being and mothering, C) Father-child relationship, D) Mother's relationship with father, E) Current partner, F) Demographics, G) Mother's family background and support, H) Environment and programs, J) Health and health behavior, K) Education and employment, L) Income
Father	1	A) Family characteristics, B) Child well-being and fathering, C) Mother-child relationship, D) Father's relationship with mother, E) Current partner, F) Demographics, G) Father's family background and support, H) Environment and programs, J) Health and health behavior, K) Education and employment, L) Income
Mother	3	A) Family characteristics, B) Child well-being and mothering, C) Father-child relationship, D) Mother's relationship with father, E) Current partner, F) Demographics, H) Mother's family background and support, I) Environment and programs, J) Health and health behavior, R) Religion, K) Education and employment, L) Income
Father	3	A) Family characteristics, B) Child well-being and fathering, C) Mother-child relationship, D) Father's relationship with mother, E) Current partner, F) Demographics, H) Father's family background and support, I) Environment and programs, J) Health and health behavior, R) Religion, K) Education and employment, L) Income
Primary care giver and in-home observation	3	A) Health and accidents, B) Family routines, C) Home toy and activity items, D) Nutrition, E) Food expenditures, F) Housing/building characteristics, G) Parental stress, H) Parental mastery, J) Discipline, K) Informal social control and social cohesion and trust, L) Exposure to violence, M) Child's behavior problems, P) Observation checklist, Q) Common areas, R) Interior of house or apartment, S) Child's appearance, T) Home scale, U) Child emotion and cooperation, V) Ending
In-home activities with child and mother	3	A) Height and weight, B) Child's Peabody Picture Vocabulary Test or TVIP, C) Walk-A-Line, D) Q-Sort, E) Mothers Peabody Picture Vocabulary Test or TVIP, F) Child Care/Employment History Calendar
Child Care Provider Survey (for center-based care)	3	A) Care provided at the center, B) Care provided for focus child (Information from director or teacher), C) Care provided for focus child (Information from teacher), E) Teacher-parent relationship, F) Teacher beliefs, G) About the childcare teacher
Child Care Center Observations	3	No clear section headings but contents include: Space and furnishings, personal care routines, language-reasoning, activities, interaction, program structure, parents and staff
Family Care Provider Survey (for family-based care)	3	A) Care provided, B) Child care routine and program, D) Provider-parent relationship, E) Child care provider beliefs, F) About the child care provider
Family Care Provider Observations	3	No clear section headings but contents include: Space and furnishings for care and learning, basic care, language and reasoning, learning activities, social development
Child Care Study Post-Observation Form	3	A) Observation checklist, B) Common areas, C) Interior of building, D) Home scale, E) Post-visit rating by interviewer
Mother	5	A) Family characteristics, B) Child well-being and mothering, C) Father-child relationship, D) Mother's relationship with father (for mothers who are or were in a relationship) E) Current partner, F) Demographics, H) Mother's family background and support, I) Environment and programs J) Health and health behavior, R) Religion K) Education and employment, L) Income
Father	5	A) Family characteristics, B) Child well-being and fathering C) Mother-child relationship D) Father's relationship with mother (for fathers who are or were in a relationship), E) Current partner, F) Demographics, H) Father's family background and support I) Environment and programs J) Health and health behavior, R) Religion K) Education and employment, L) Income
Primary care giver and in-home observation	5	A) Health and accidents, B) Family routines, C) Home toy and activity items, D) Nutrition, E) Housing/building characteristics, F) Parental stress and mastery, G) Discipline, H) Exposure to violence, J) CPS contact, K) Food expenditures, L) Child's behavior, N) Activities, P) Observation checklist, Q) Common areas, R) Interior of house or apartment, S) Child's appearance, T) Home scale, U) Child emotion and cooperation, V) Ending
In-home activities with child and mother	5	A) Weight/height, B) Peabody Picture Vocabulary Test with child, C) Woodcock-Johnson Letter-Word activity with child, D) Attention sustained task, E) Child care employment history calendar, F) Five-minute speech sample, G) Peabody Picture Vocabulary Test with mother
Teacher	5	A) Information specific to the participating child, B) Academic skills specific to the participating child, C) Classroom behavior and social skills specific to the participating child, D) Classroom characteristics, E) Class resources and activities, F) School climate and environment, G) General information about teacher
Mother	9	A) Core mother interview: Family characteristics, household roster, marital, and fertility history, B) Bio father contributions and resources, C) Mother's relationship with father, D) Current partner, E) Mother's family background and support, F) Environment and programs, G) Health and health behavior, H) Religion, I) Education and employment, J) Income, K) Secondary caregiver
Father	9	A) Core father interview: Family characteristics, household roster, marital, and fertility history, B) Bio mother and bio father contributions and resources, C) Father's relationship with mother, D) Current partner, E) Father's family background and support, F) Environment and programs, G) Health and health behavior, H) Religion, I) Education and employment, J) Income, K) Secondary caregiver
Primary care giver	9	A) Introduction to non-parental caregiver survey, B) Mother-child relationship, C) Father-child relationship, D) Demographics, E) Income, education, and employment, F) Health and wellbeing, G) Environment, H) Health and accidents, I) Family routines and home life, J) Nutrition, K) Parental stress and mastery, L) Child's education, M) Child's neighborhood
Interviewer observation	9	A) Observation checklist, B) Common areas, C) Interior of house or apartment, D) Child's appearance, E) Home scale, F) Child emotion and cooperation, G) Ending
Child	9	A) Parental supervision and relationship, B) Parental discipline, C) Sibling relationships, D) Routines, E) School, F) Early delinquency, G) Task completion and behavior, H) Health and safety, I) Closing
In-home activities with child and primary care-giver	9	No clear section headings but activities include: Consent, Child assessment (PPVT, Digit span, Woodcock-Johnson Tests 9 and 10), Primary caregiver self-administered questionnaire, Health measures, Saliva sample, Biological mother weight, Child weigh/height, Primary caregiver open-ended responses
Teacher	9	A) General information, B) Classroom behavior and social skills specific to the participating child, C) Information specific to the participating child, D) Parent/guardian involvement, E) Classroom characteristics, F) School climate and environment, G) General information about teacher


Birth
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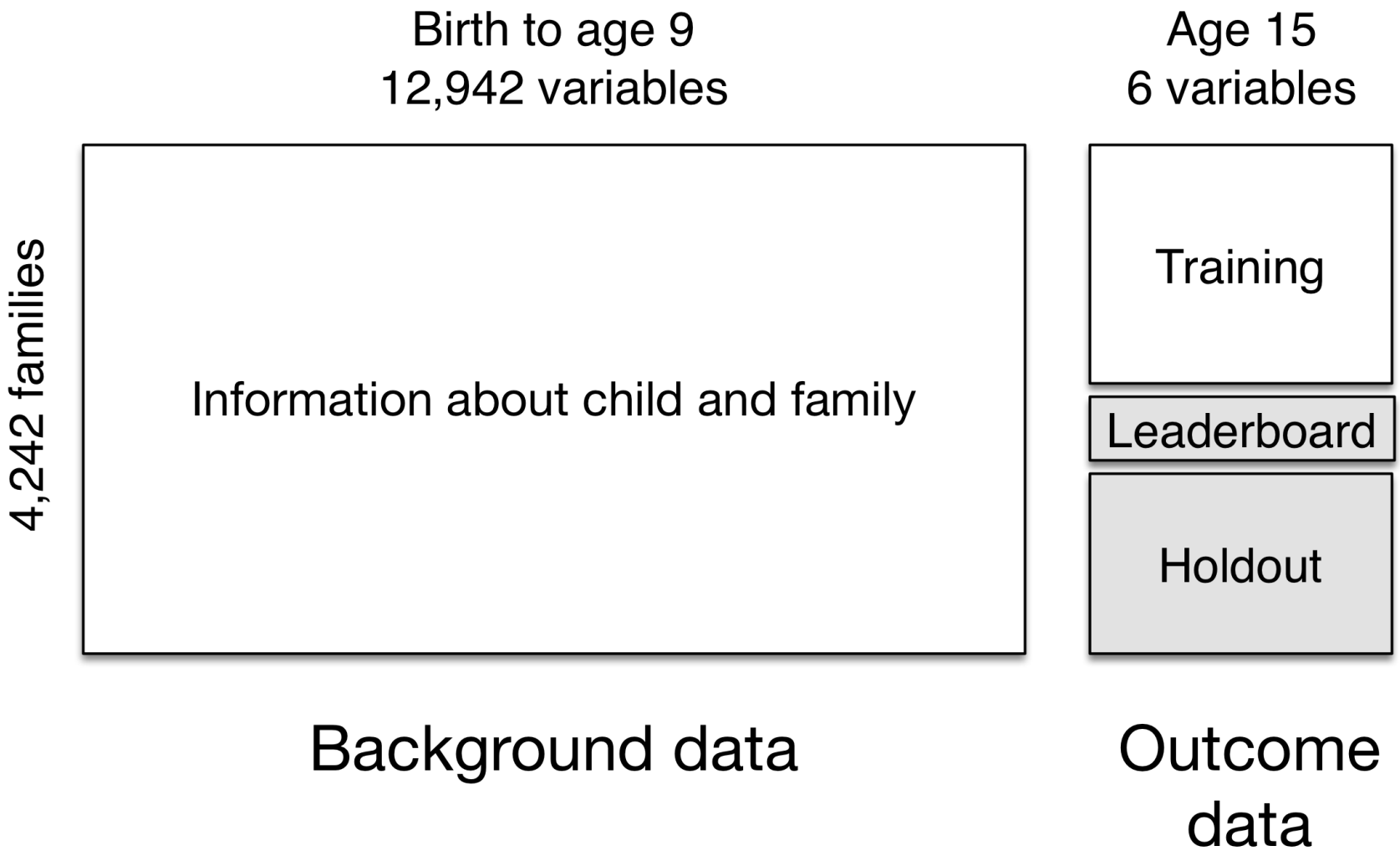
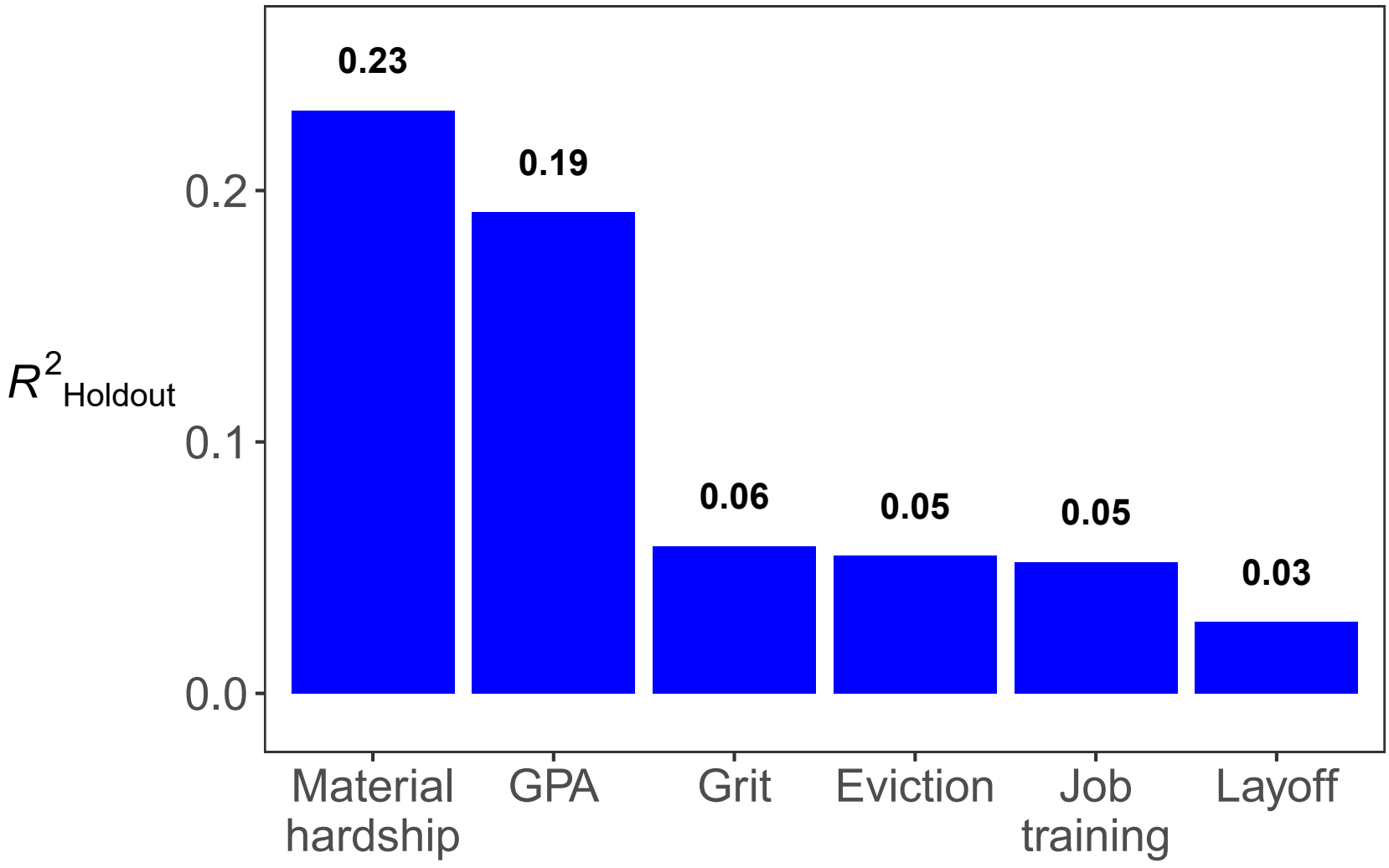
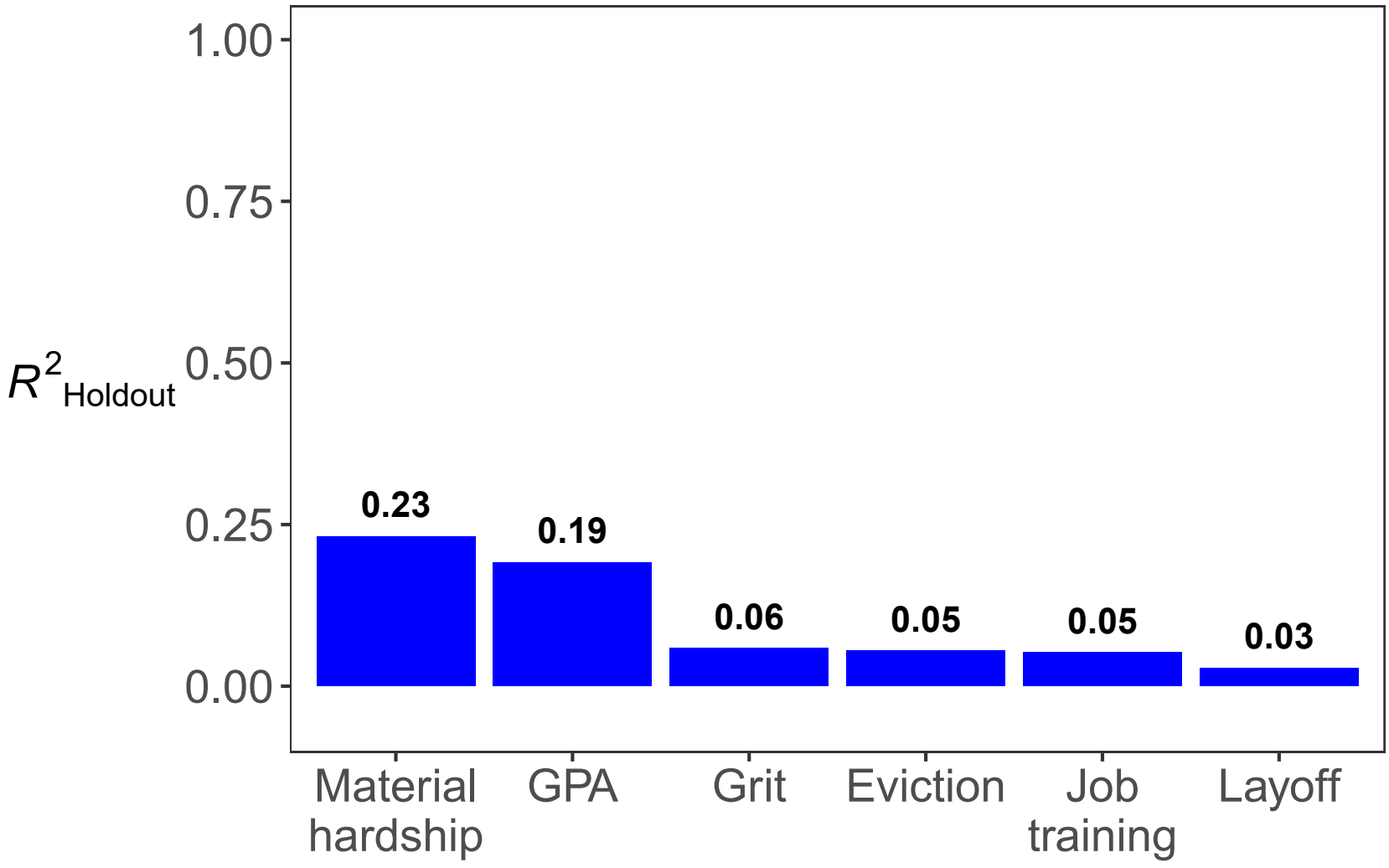

Birth to age 9
12,942 variables
Age 15
6 variables
4,242 families
Information about child and family
Training
Leaderboard
Holdout
Background data
Outcome data

Using a large, high-quality social science dataset collected since birth and modern machine learning methods, how accurately can we predict outcomes from children, parents, and families?

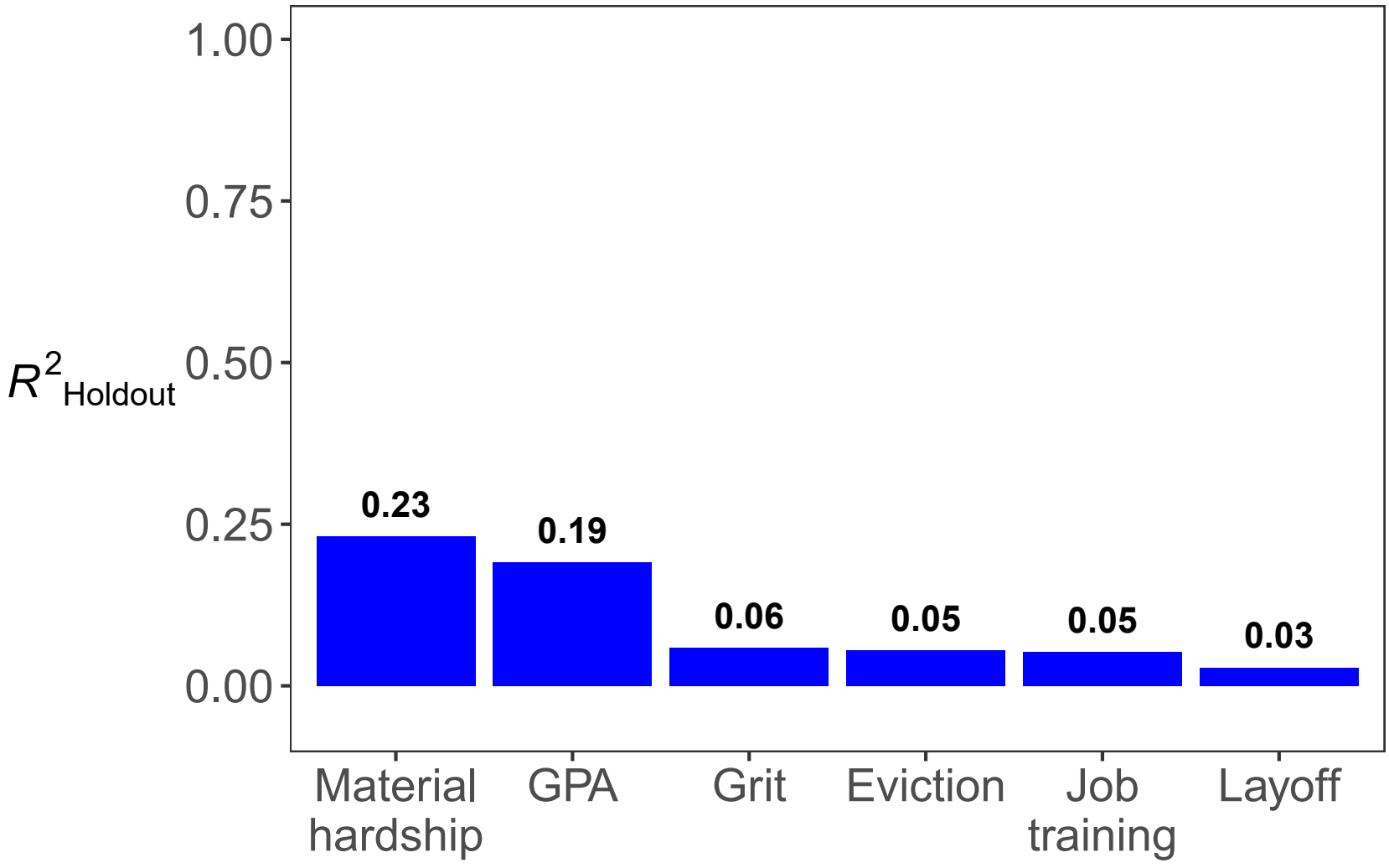
$$R^2_{holdout} = 1 - \frac{\sum_{i \in \text{holdout}} (\hat{y}_i - y_i)^2}{\sum_{i \in \text{holdout}} (\bar{y}_{train} - y_i)^2}$$

Six outcomes: Child grade point average (GPA), Child grit, Household eviction, Household material hardship, Adult job loss, Adult job training


R^2_{Holdout}
0.0
0.1
0.2
0.23
0.19
0.06
0.05
0.05
0.03
Material hardship
GPA
Grit
Eviction
Job training
Layoff


R^2_{Holdout}
1.00
0.75
0.50
0.25
0.00
0.23
0.19
0.06
0.05
0.05
0.03
Material hardship
GPA
Grit
Eviction
Job training
Layoff

Is this any better than a benchmark model?


R^2_{Holdout}
1.00
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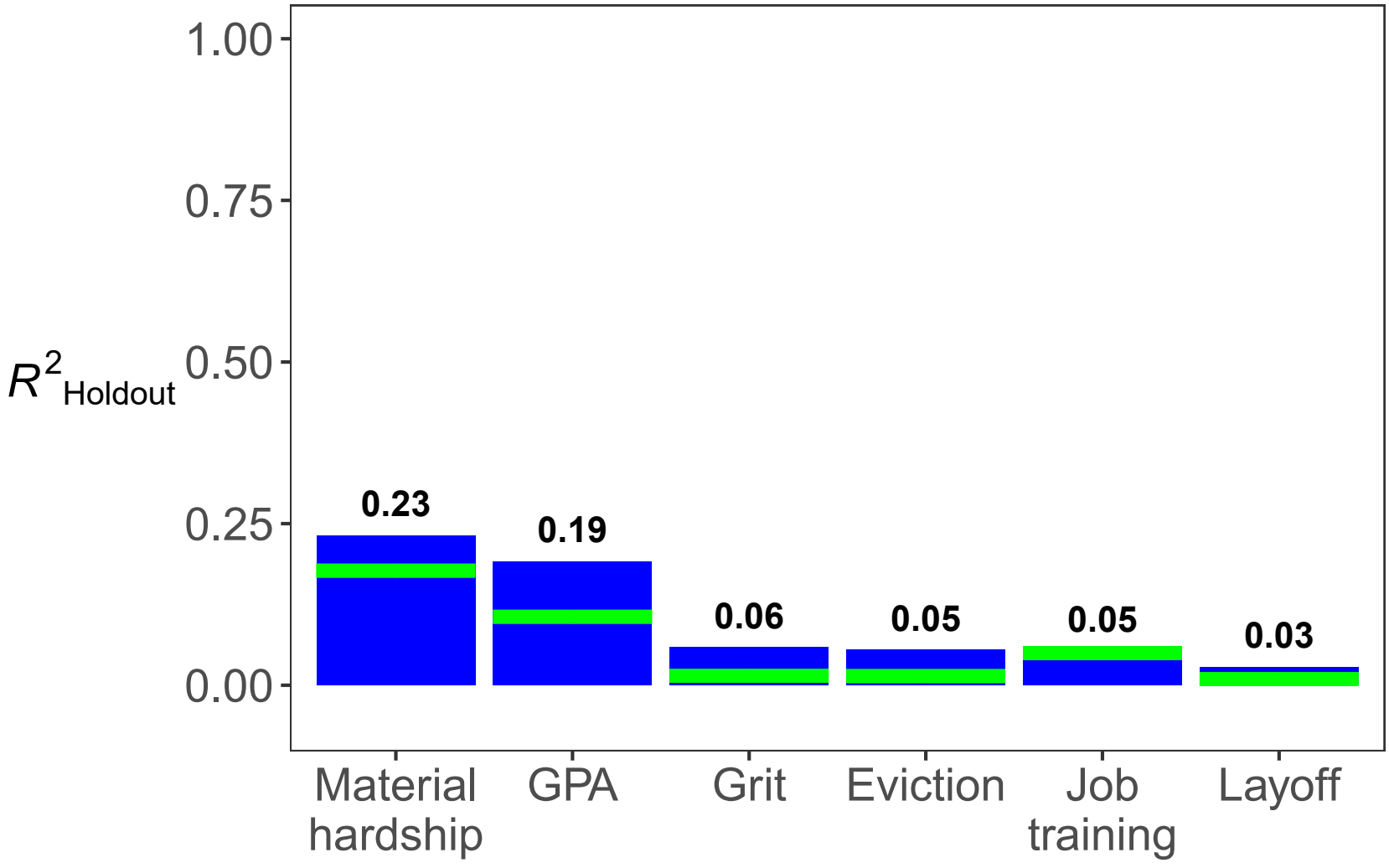
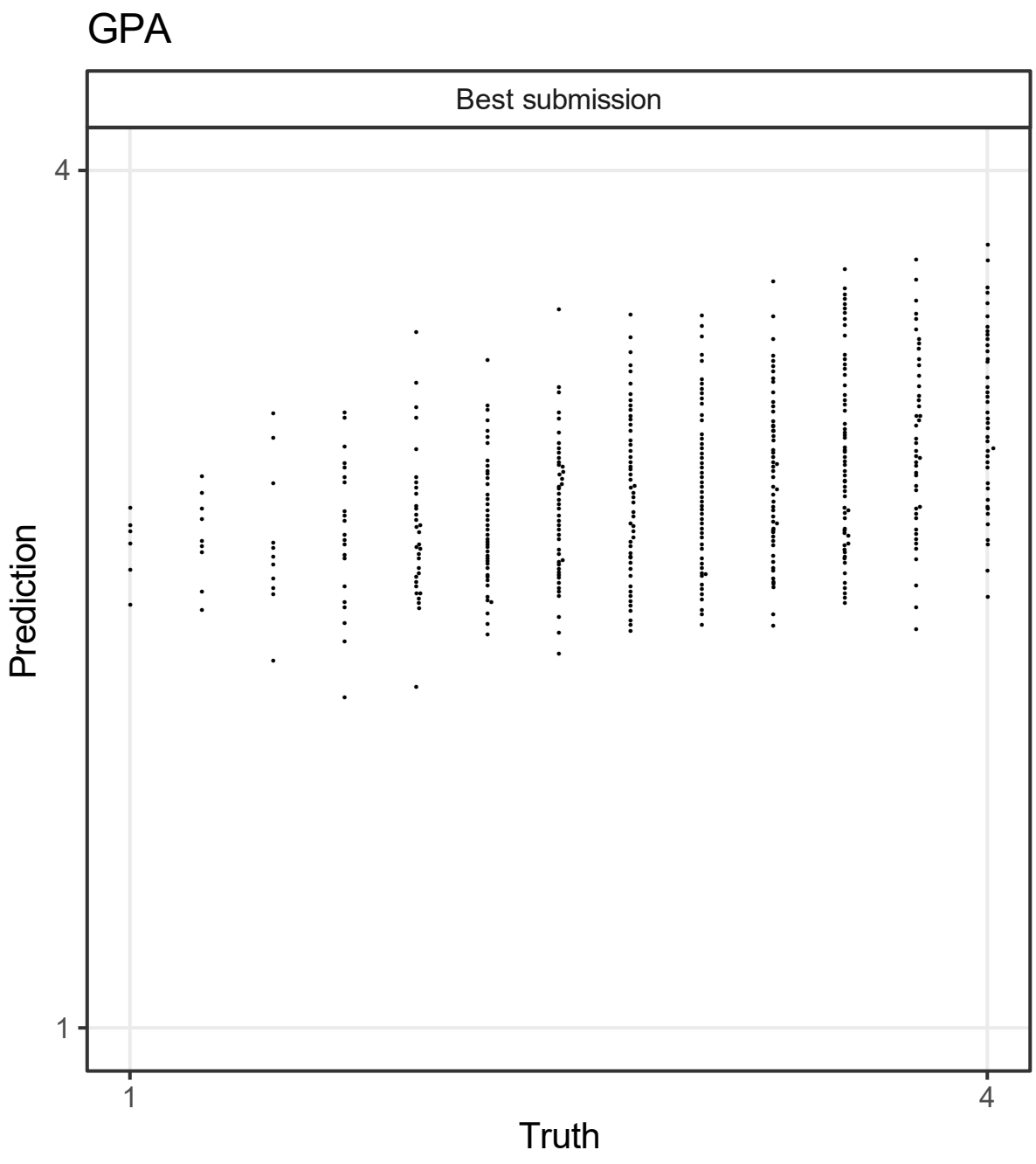
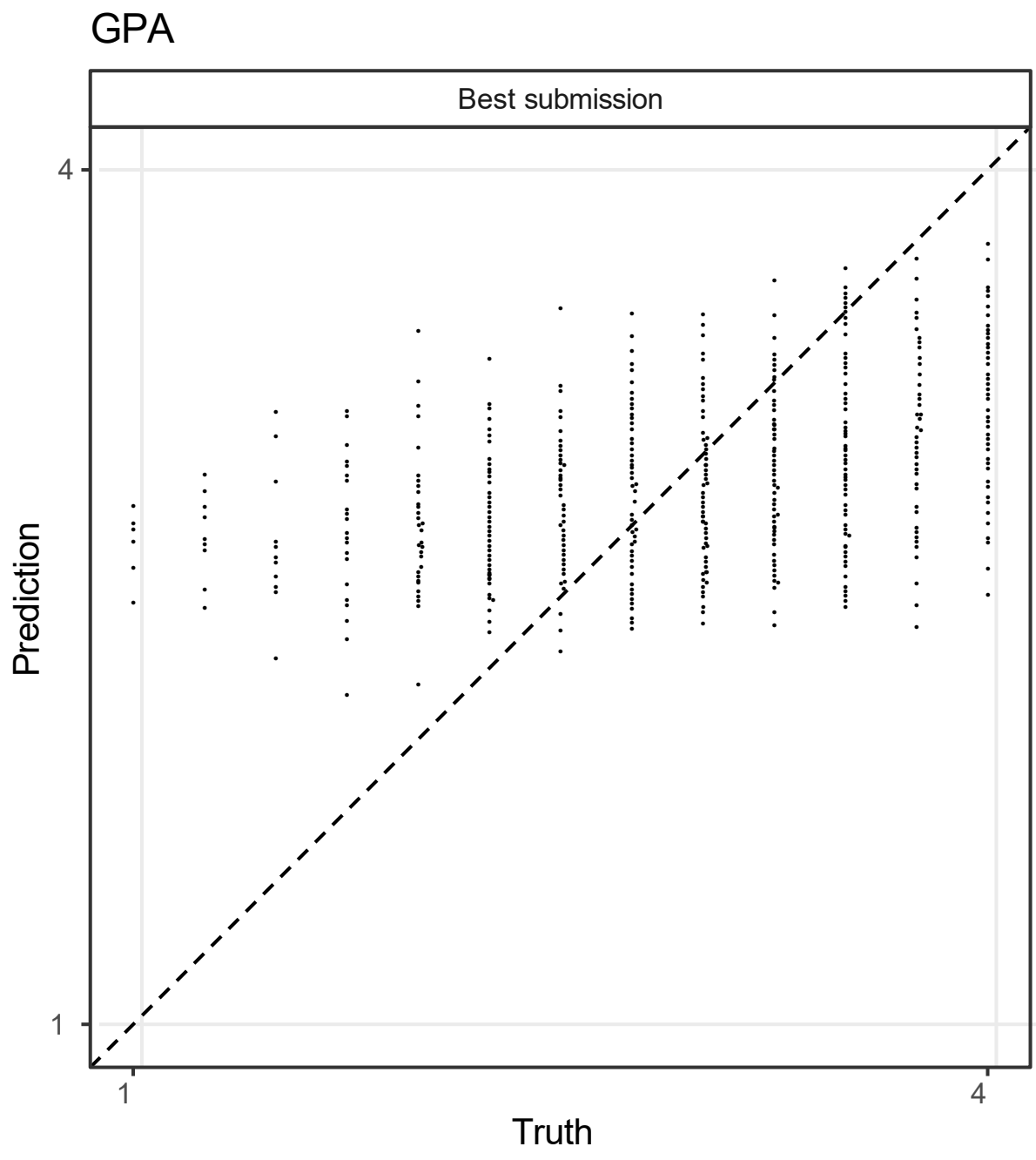
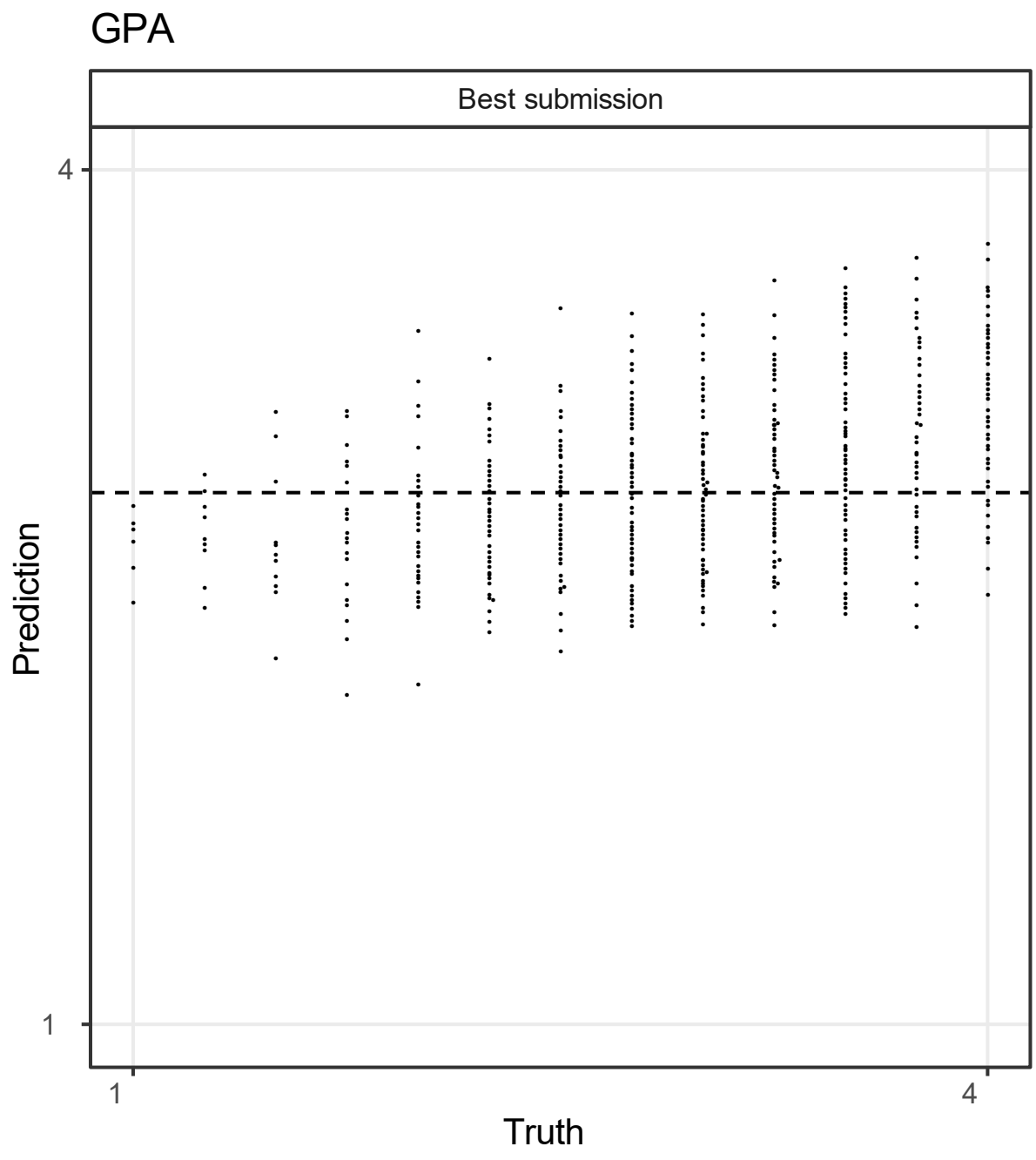


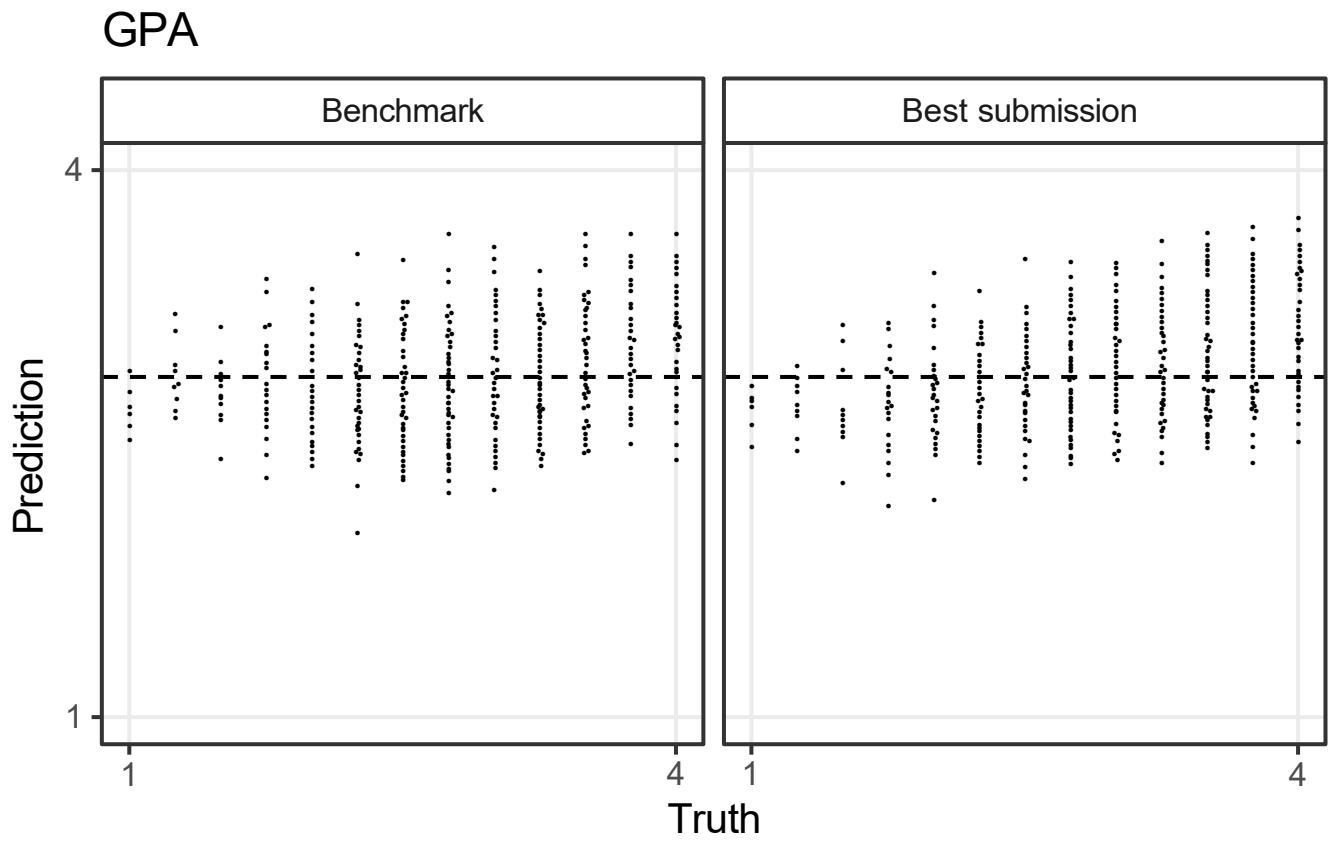
Green line: 4 variable regression model

How can I get a feel for this level of predictability?

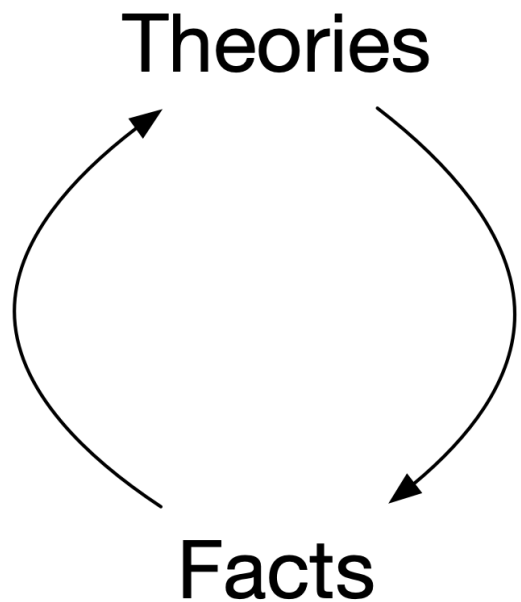

GPA
Best submission
4
1
Prediction
1
4
Truth


GPA
Best submission
Prediction
Truth
4
1
1
4


GPA
Best submission
4
1
Prediction
1
4
Truth

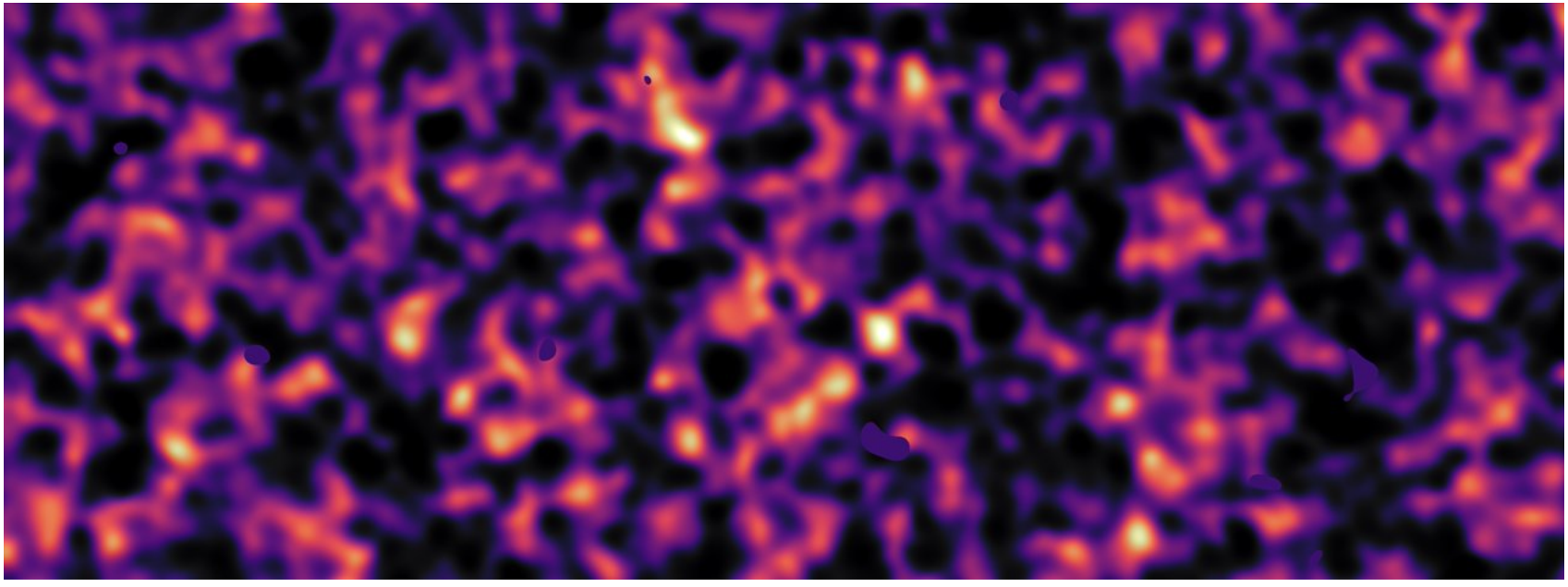

GPA
Benchmark
Best submission
Prediction
4
1
1
4
1
4
Truth

What's going on?


Theories
Facts

"Origins of unpredictability in life trajectory prediction"

Ian Lundberg, Rachel Brown-Weinstock, Susan Clampet-Lundquist, Sarah Gold, Tim Nelson, Vicki Yang, Kathryn Edin, and Matthew Salganik



https://en.wikipedia.org/wiki/Dark_matter#/media/File:Dark_matter_map_of_KiDS_survey_region_(region_G12).jpg

- In-depth semi-structured interviews with young adult and primary care giver (separately)

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- About 40 families spread over 3 cities

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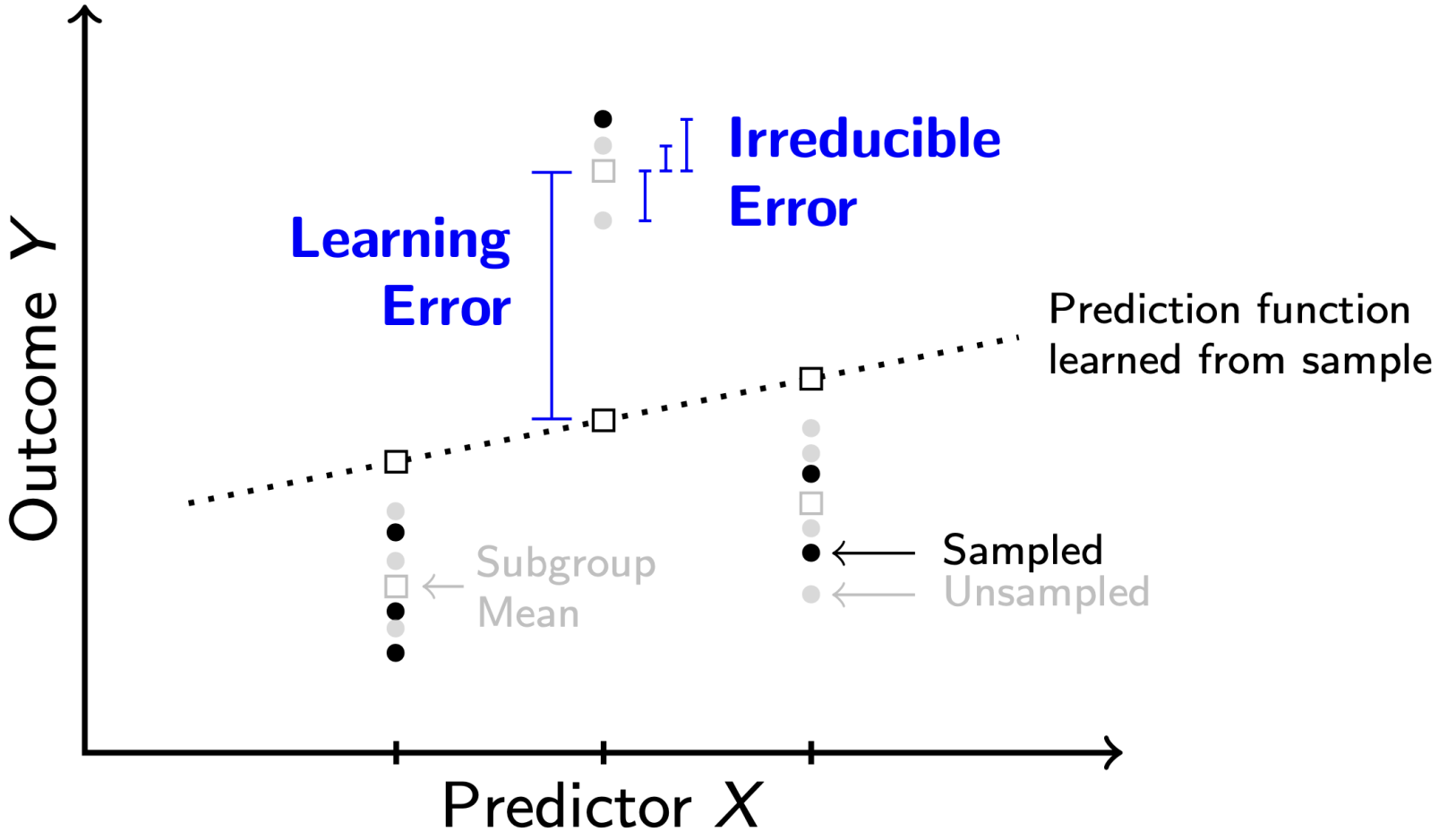
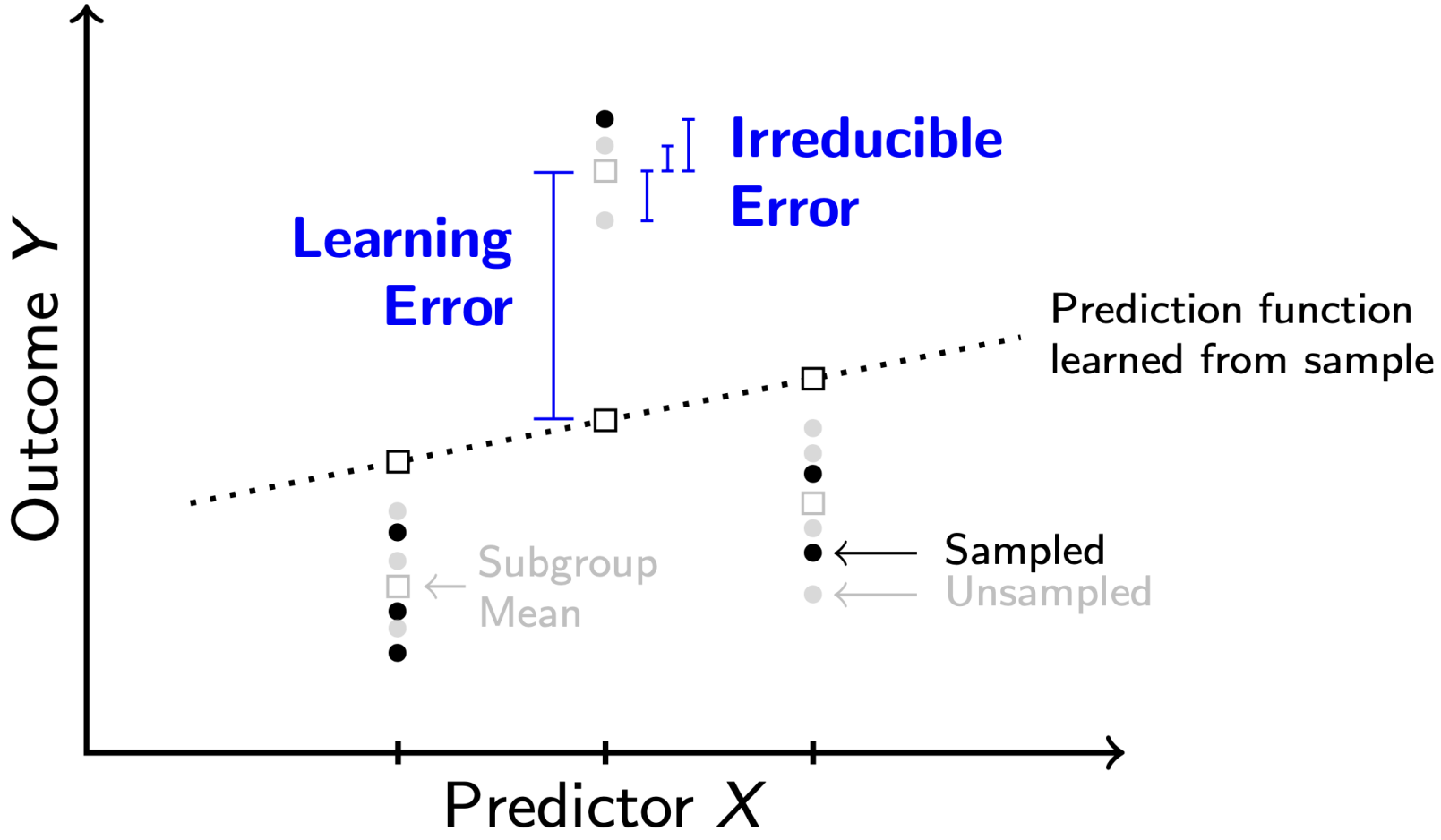
Reading and discussing the interview transcripts, we inductively settled into a conceptual framework


Irreducible
Error
Learning
Error
Prediction function
learned from sample
Subgroup
Mean
Sampled
Unsampled
Outcome Y
Predictor X



$$\underbrace{\mathrm{E}\left(\left(Y-\hat{f}_S(\vec{X})\right)^2\right)}_{\textbf{Prediction Error}} = \underbrace{\mathrm{E}\left(\mathrm{V}\left(Y \mid \vec{X}\right)\right)}_{\textbf{Irreducible Error}} + \underbrace{\mathrm{E}\left(\left(\hat{f}_S(\vec{X})-\mathrm{E}(Y \mid \vec{X})\right)^2\right)}_{\textbf{Learning Error}}$$

Prediction Error
Expected squared prediction error

Irreducible Error
Outcome variance given X

Learning Error
Expected squared error for the conditional mean

Irreducible error

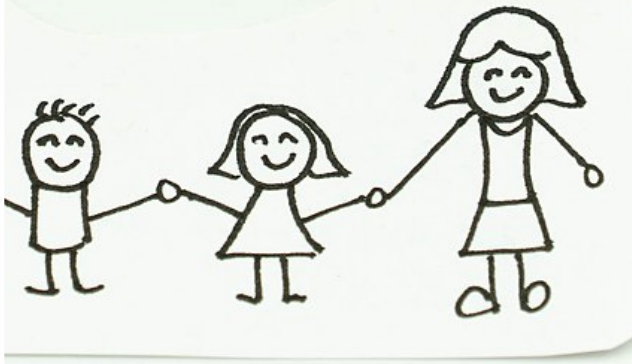
Three sources of irreducible error:

- Unmeasurable features
- Unmeasured features
- Imperfectly-measured features

Bella

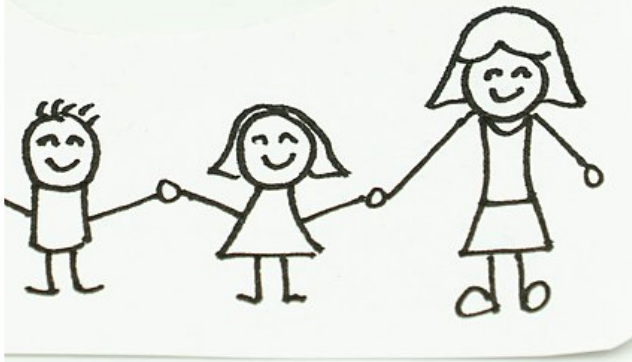
Source: Wikimedia

Father passed away



Source: Wikimedia

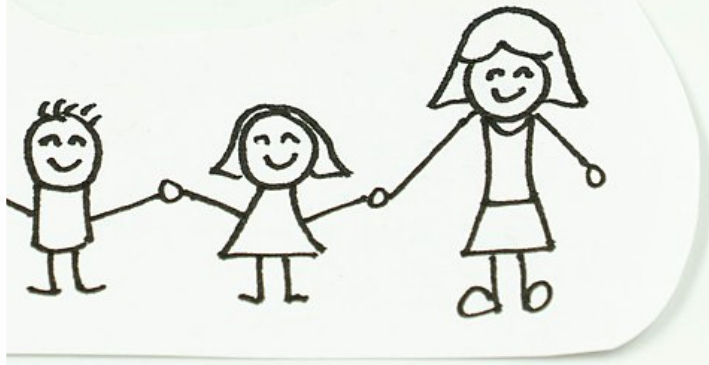
Father passed away



Mother depressed

Source: Wikimedia

Father passed away

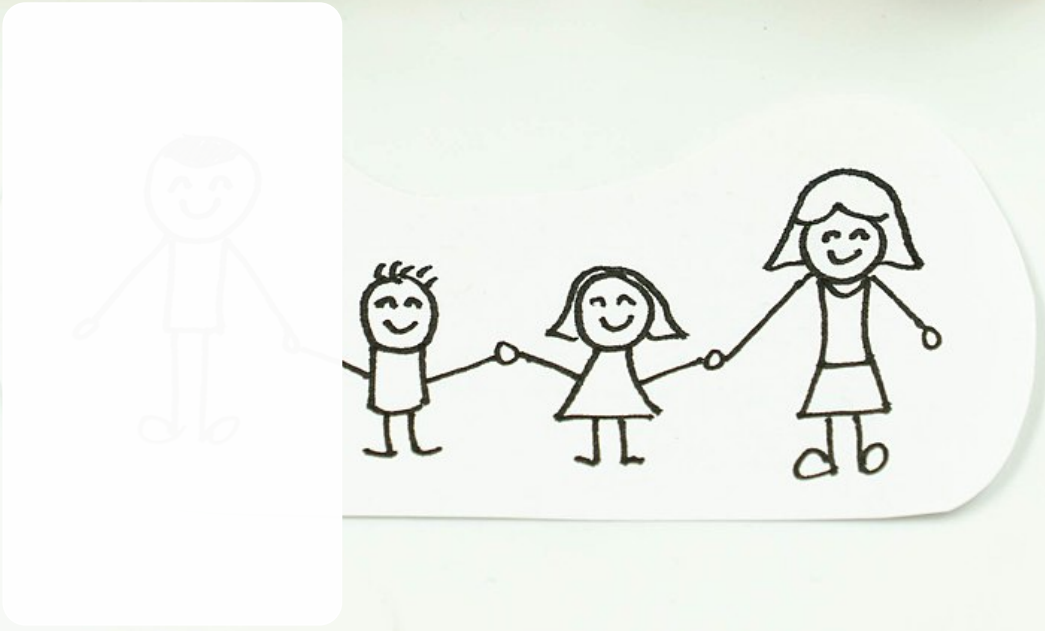


Mother depressed

Source: Wikimedia

"When he passed away, she checked out. She was depressed. . . she was in her own world. Then, [my brother and I] were in our own world...It wasn't really a relationship."

Father passed away



Mother depressed

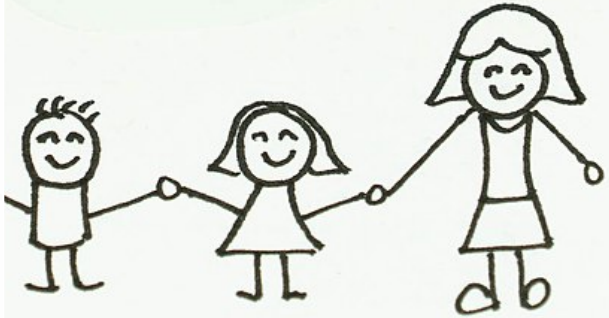
Source: Wikimedia

"When he passed away, she checked out. She was depressed. . . she was in her own world. Then, [my brother and I] were in our own world...It wasn't really a relationship."

Predicted GPA: 3.06.

Bella

Father passed away



Mother depressed

Source: Wikimedia

"When he passed away, she checked out. She was depressed. . . she was in her own world. Then, [my brother and I] were in our own world...It wasn't really a relationship."

Predicted GPA: 3.06. Actual GPA: 1.50

Lola

Mother engaged in illegal activities

Lola

Mother engaged in illegal activities

- elderly neighbor got Lola ready for school many mornings

Lola

Mother engaged in illegal activities

- elderly neighbor got Lola ready for school many mornings
- grandparents remodeled their basement to house Lola and her mother for a while

Lola

Mother engaged in illegal activities

- elderly neighbor got Lola ready for school many mornings
- grandparents remodeled their basement to house Lola and her mother for a while
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Lola

Mother engaged in illegal activities

- elderly neighbor got Lola ready for school many mornings
- grandparents remodeled their basement to house Lola and her mother for a while
- aunt employed Lola's mother in a family business

Predicted GPA: 3.04.

Lola

Mother engaged in illegal activities

- elderly neighbor got Lola ready for school many mornings
- grandparents remodeled their basement to house Lola and her mother for a while
- aunt employed Lola's mother in a family business

Predicted GPA: 3.04. Actual GPA: 3.75.

Hennessy

Hennessy

A2E. How close do you feel to your mom? Would you say…

Extremely close, ... 1
Quite close,..... 2
Fairly close, or, ... 3
Not very close?..... 4
REFUSED ..... -1
DON'T KNOW ..... -2

Hennessy

A2E. How close do you feel to your mom? Would you say…

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

Hennessy

A2E. How close do you feel to your mom? Would you say…

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

"We always bickered and fought...I caught myself begging for my mom... 'Mom, I need you,'...and she. . . just like blatantly ignored me."

Hennessy

A2E. How close do you feel to your mom? Would you say…

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

Mom told her, "[y]ou better start treating me better, because I might not live that long"

Hennessy

A2E. How close do you feel to your mom? Would you say…

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

"I couldn't even focus in class...I was shaking. That was all I could think about. I was, like, crying in school, and they [school staff] had no idea what was wrong with me."

Hennessy

A2E. How close do you feel to your mom? Would you say...

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

"I couldn't even focus in class...I was shaking. That was all I could think about. I was, like, crying in school, and they [school staff] had no idea what was wrong with me."

Predicted GPA: 2.71.

Hennessy

A2E. How close do you feel to your mom? Would you say...

	Extremely close,	1
	Quite close,	2
	Fairly close, or,	3
→	Not very close?	4
	REFUSED	-1
	DON'T KNOW	-2

"I couldn't even focus in class...I was shaking. That was all I could think about. I was, like, crying in school, and they [school staff] had no idea what was wrong with me."

Predicted GPA: 2.71. Actual GPA: 1.25.

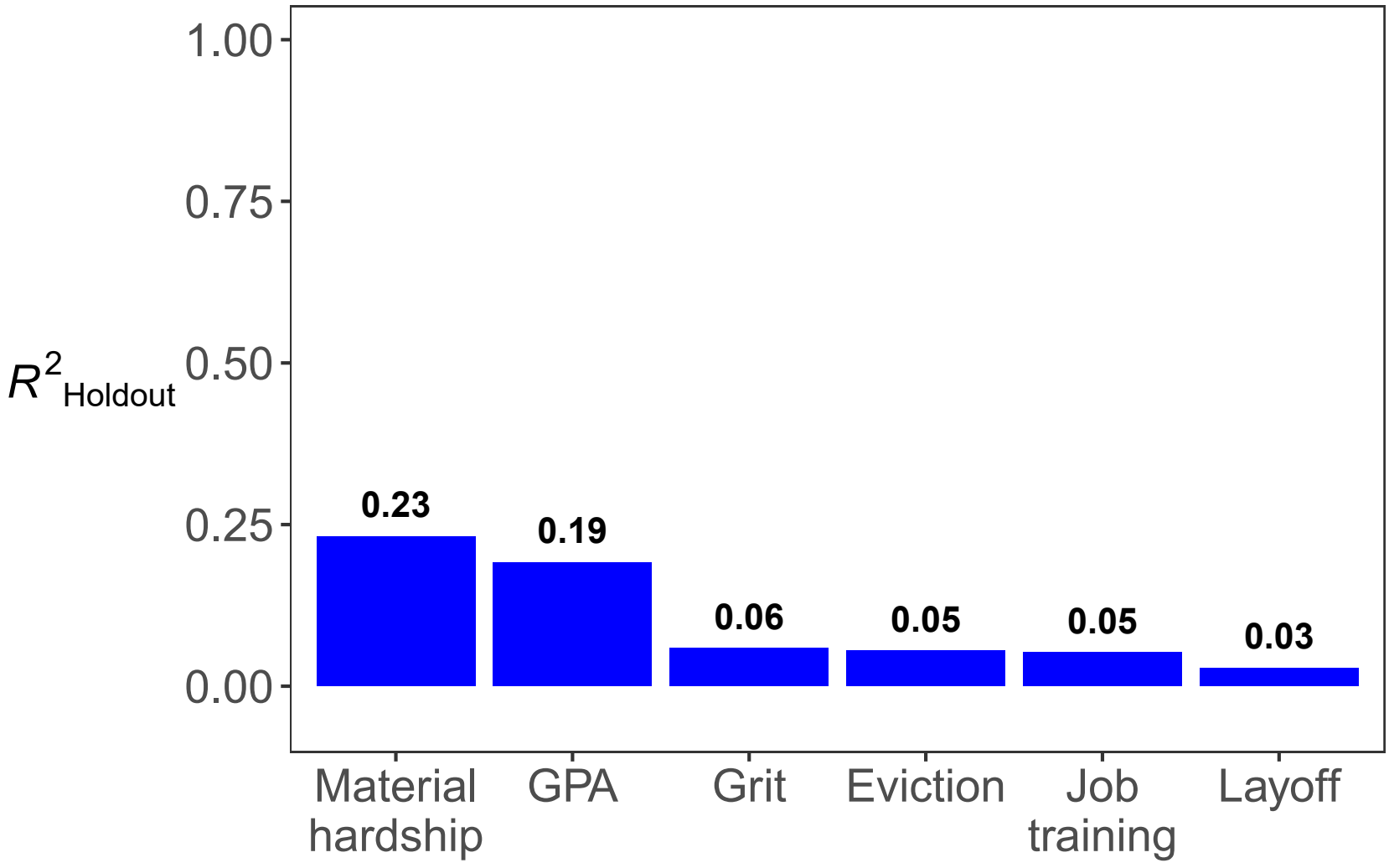
Irreducible error

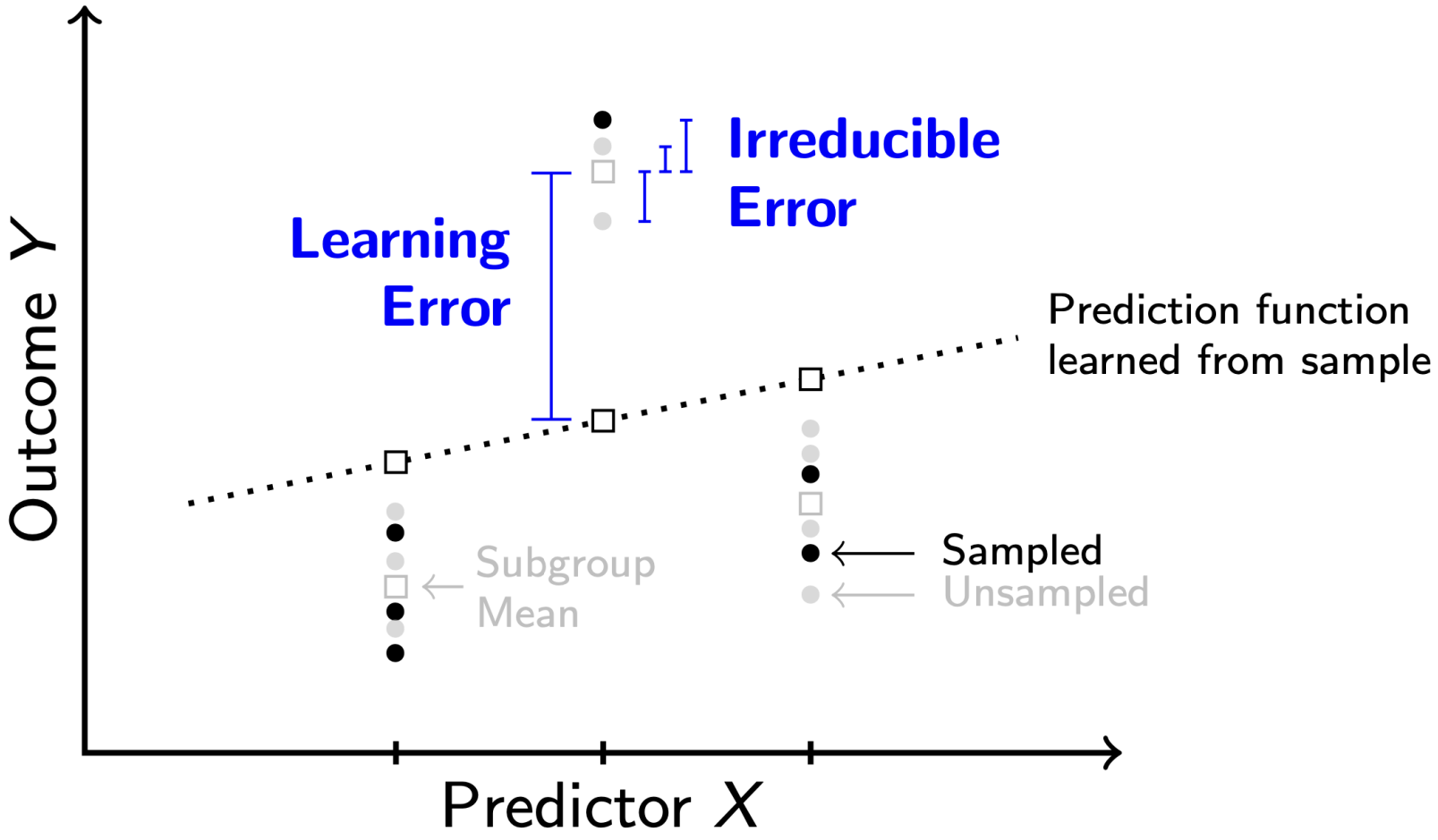
Three sources of irreducible error:

- Unmeasurable features (Bella's story)
- Unmeasured features (Lola's story)
- Imperfectly-measured features (Hennesey's story)

For more information, see our paper coming out this week in the *Proceedings of the National Academy of Sciences*.

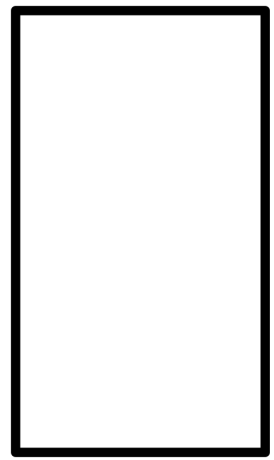
Discussion and next steps


R^2_{Holdout}
1.00
0.75
0.50
0.25
0.00
0.23
0.19
0.06
0.05
0.05
0.03
Material hardship
GPA
Grit
Eviction
Job training
Layoff


Irreducible
Error
Learning
Error
Prediction function
learned from sample
Subgroup
Mean
Sampled
Unsampled
Outcome Y
Predictor X

Features

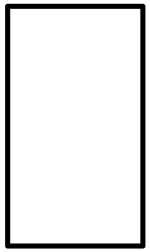
Cases



Short and thin

Features

Cases



Short and thin

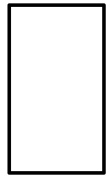
Features

Cases

Short and wide

Features

Cases



Short and thin

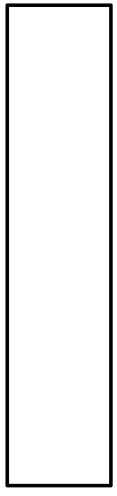
Features

Cases

Short and wide

Features

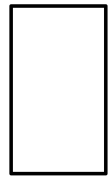
Cases



Tall and thin

Features

Cases



Short and thin

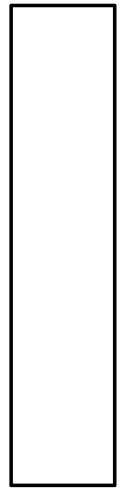
Features

Cases

Short and wide

Features

Cases



Tall and thin

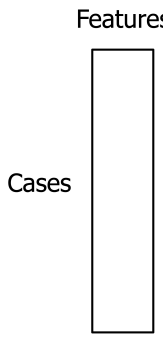
Features

Cases

Tall and wide

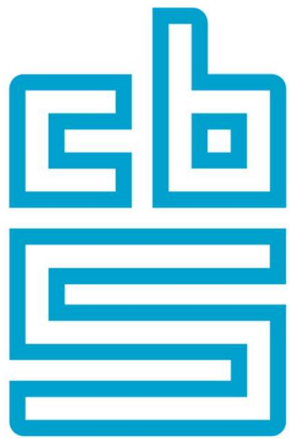
Short and thin

Short and wide



Tall and thin

Tall and wide



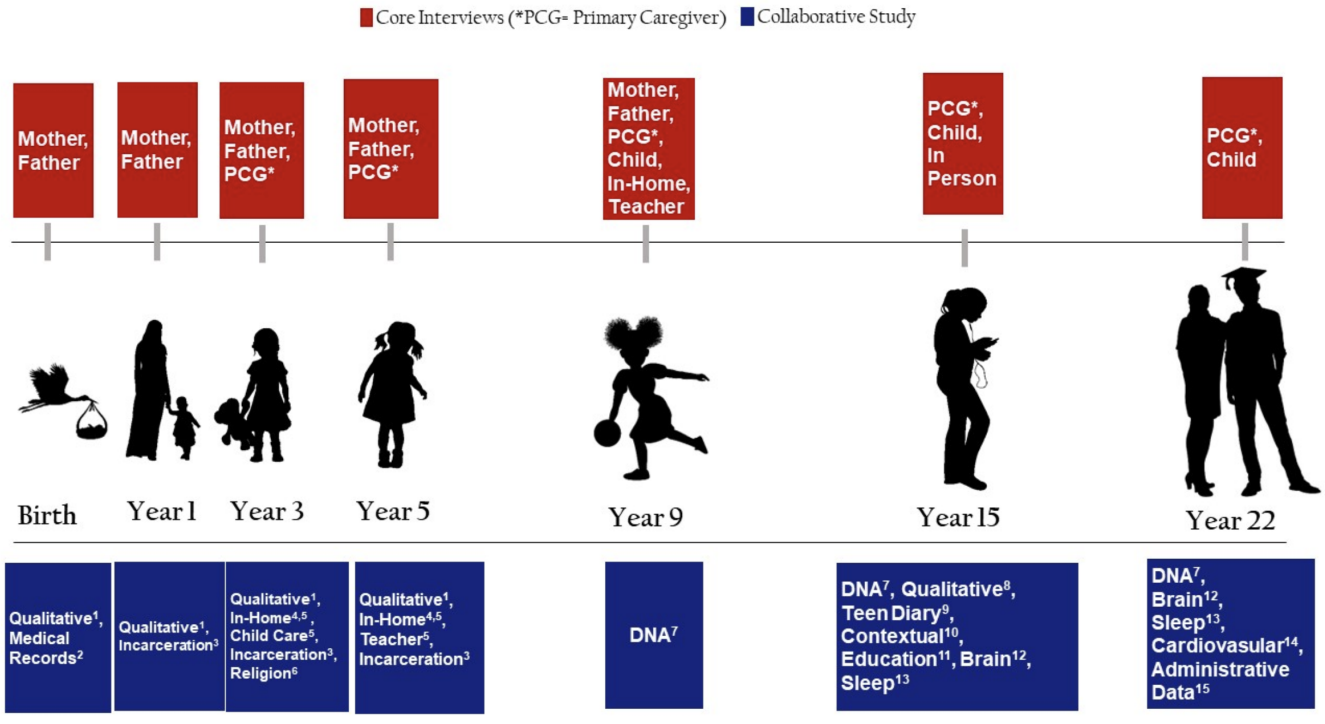
Statistics
Netherlands

Computational social science

- v1: social science $\leftrightarrow$ data science

Computational social science

- v1: social science $\leftrightarrow$ data science
- v2: social science $\leftrightarrow$ AI


Core Interviews (*PCG= Primary Caregiver)
Collaborative Study
Mother, Father
Mother, Father
Mother, Father, PCG*
Mother, Father, PCG*
Mother, Father, PCG*, Child, In-Home, Teacher
PCG*, Child, In Person
PCG*, Child
Birth
Year 1
Year 3
Year 5
Year 9
Year 15
Year 22
Qualitative[1], Medical Records[2]
Qualitative[1], Incarceration[3]
Qualitative[1], In-Home[4,5], Child Care[5], Incarceration[3], Religion[6]
Qualitative[1], In-Home[4,5], Teacher[5], Incarceration[3]
DNA[7]
DNA[7], Qualitative[8], Teen Diary[9], Contextual[10], Education[11], Brain[12], Sleep[13]
DNA[7], Brain[12], Sleep[13], Cardiovasular[14], Administrative Data[15]

Thank you