Unfolding Structure in the Drawings of Cubes

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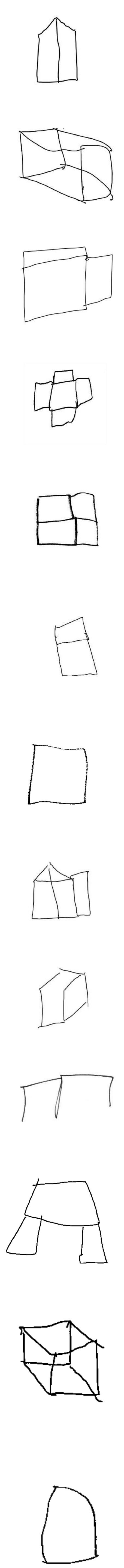
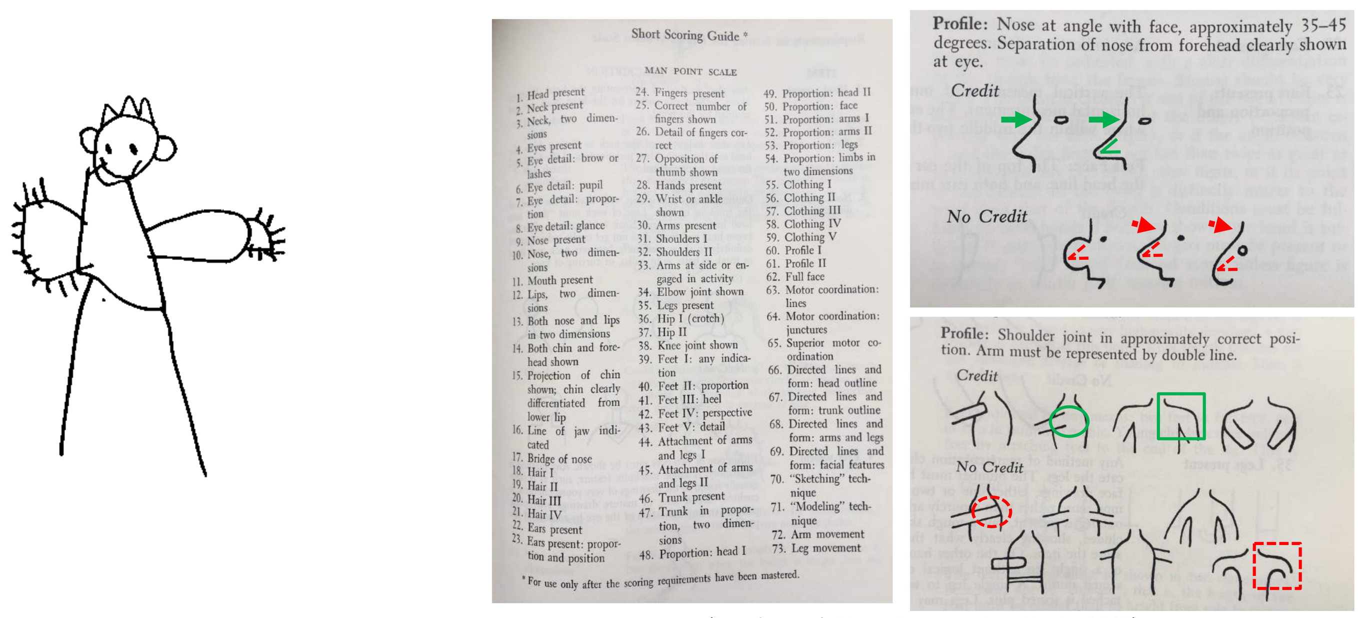


Background

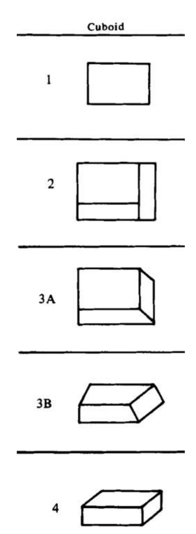
Children's drawings have a long and diverse history of use as primarily nonverbal assessment of children's cognitive, emotional, and motor function. The most common approach to assign progress or delay in children's development when using drawing tasks are checklists marking the presence or absence of intuitively-derived features. The most influential drawing checklist is described by Florence Goodenough in her 1926 book, *Measurement of intelligence by drawings* which outlines the Draw-A-Man test, a checklist system to identify important features of human figures (e.g., body parts, facial features).

More recent research on drawings has extended the checklist approach to assess shape drawings (e.g., cubes). In the present research, we explore how recent advances leveraging neural network models and crowd-sourced perceptual judgements may be applied to cube drawings. We consider the predictive relationship of children's cube and human figure drawings on the cognitive/motor task of paper folding.

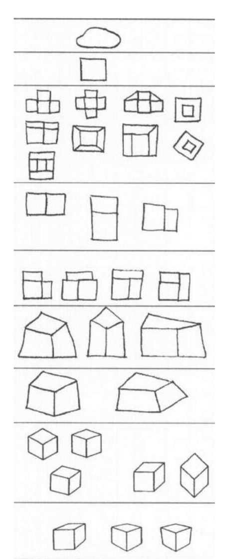


(Goodenough-Harris Drawing Test; Harris, 1963)

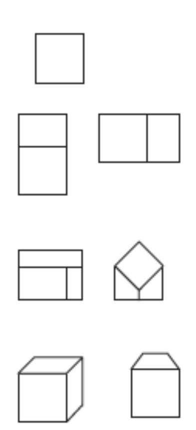
Does the checklist approach underrepresent structure in children's drawings?



(Mitchelmore, 1978)



(Cox & Perara, 1998)



(Lange-Küttner & Ebersbach, 2013)

Score 0 – Scribbles / unattached lines

Score 1 – Single Square

Score 2 – Square or rectangle + 1 Shape
No attempt to capture 3D

Score 3 – Square + 2 or 3 Shapes
No real attempt to capture 3D

Score 4 – Attempts to capture 3D
Poorly executed

Score 5 – Attempts to capture 3D
By Unfolding

Score 6 – Attempts to capture 3D
but with limited sides or with worse execution than 7

Score 7 – Attempts to capture 3D
Not quite well executed

Score 8 – Nice 3D Cube

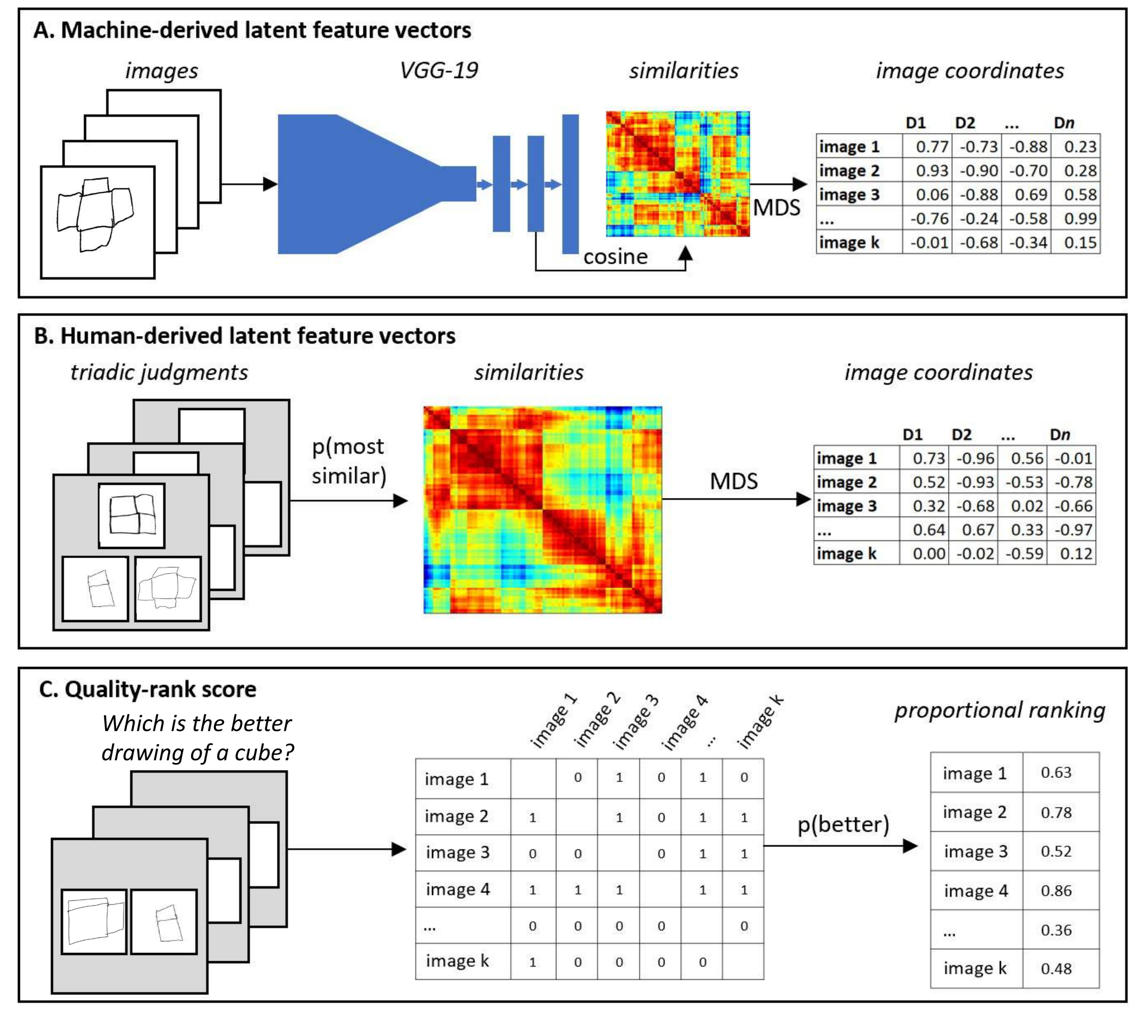
The Current Study

129 Children from age 2 to 12, 53% female; 25 Adults

65 Children contributed a Cube Drawing / Paper Folding

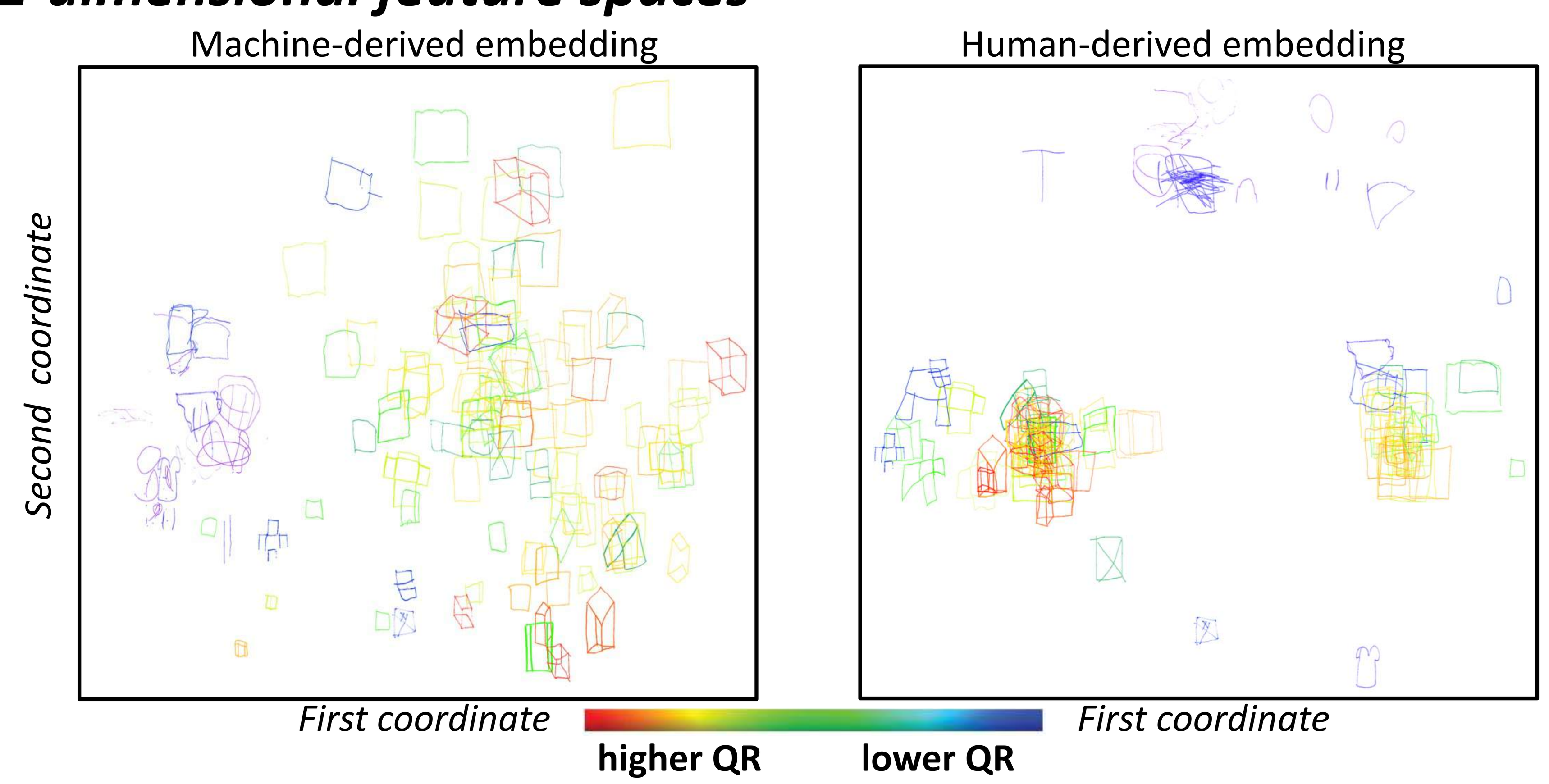
- M_{age} = 6 years; $Range_{age}$ = 4 – 12 years
- 65% female
- Recruited for a larger study looking at drawing on different media (Kirkorian et al., 2020)

Contemporary approaches (Jensen et al., 2023; 2024)



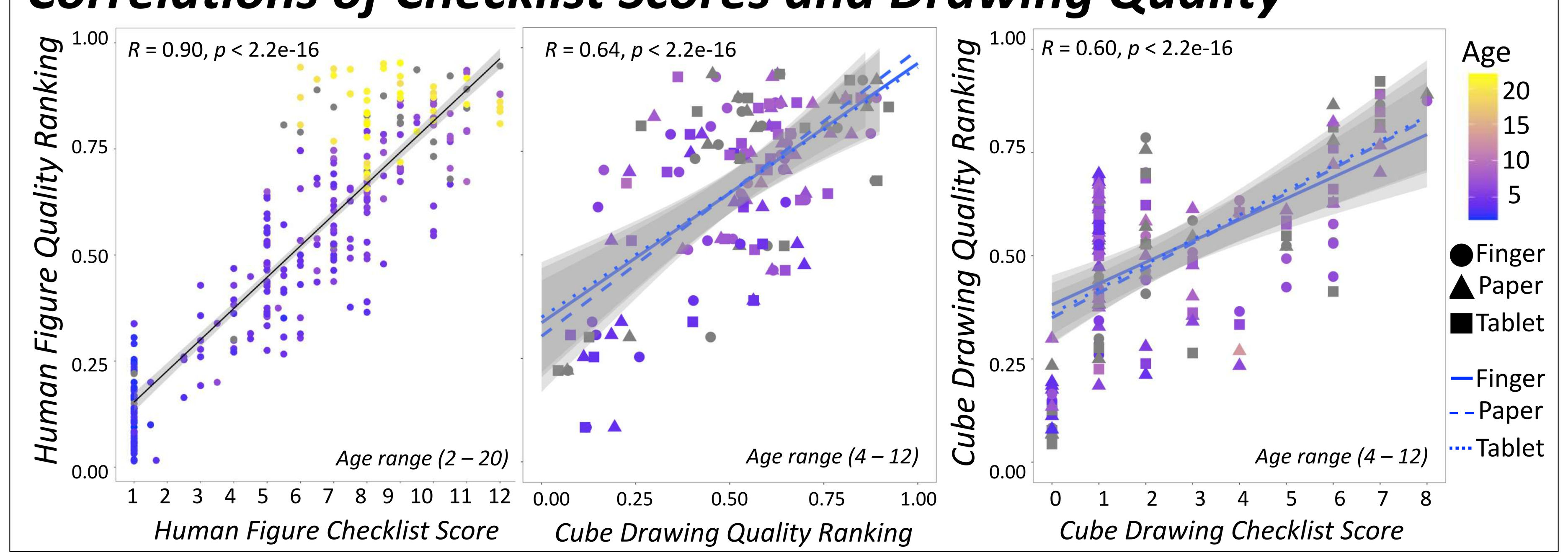
Note. Contemporary approaches for the identification of latent structure in drawings through dimensionality reduction. (A. convolutional neural net; B. triadic judgements task; C. dueling-bandits task)

2-dimensional feature spaces

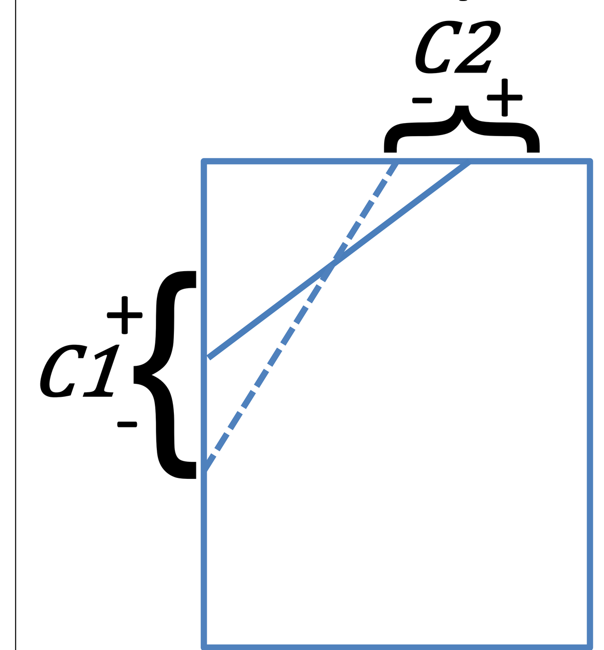


Note. Each drawing is placed according to its coordinates in the corresponding 2D space, with the color indicating the Quality Rank (QR) score of the drawing, with hotter colors indicating higher-ranked drawings and cool colors showing low-ranked drawings.

Correlations of Checklist Scores and Drawing Quality



Outcomes – Paper Folding



$$offset = \frac{|C1| + |C2|}{2}$$

$$angle = |C2 - C1|$$

Used stepwise regression including our novel metrics to predict paper folding scores

Results varied by media

Marker on Paper > Stylus on Tablet >> Finger on Tablet

Cube Drawings – Marker on Paper

Dependent Variable	*n*	Baseline	Cube Checklist	Cube Quality Ranking	Cube Human Embedding	Cube Machine Embedding	Cube QR * Human Embedding	Cube QR * Machine Embedding
Offset	41	*adj* = .06 *mult* = .09	*adj* = .18 *mult* = .20	*adj* = .10 *mult* = .26	*adj* = **.26*** *mult* = **.43***	*adj* = .17 *mult* = .56	*adj* = .41 *mult* = .78	*adj* = .76 *mult* = .99
Angle	41	*adj* = .00 *mult* = .08	*adj* = **.11*** *mult* = **.13***	*adj* = **.20*** *mult* = **.34***	*adj* = .16 *mult* = .47	*adj* = .14 *mult* = .48	*adj* = **.48*** *mult* = **.72***	*adj* = .41 *mult* = .97
comparison model:		*null*	*Baseline*				*Quality Ranking *Baseline*	

Human Figure Drawings

Dependent Variable	*n*	Baseline	Human Figure Checklist	Human Figure Quality Ranking	Human Figure Human Embedding	Human Figure Machine Embedding	Human Figure QR * Human Embedding	Human Figure QR * Machine Embedding
Offset	34	*adj* = **.10*** *mult* = **.13***	*adj* = .28 *mult* = .45	*adj* = .31 *mult* = .47	*adj* = **.51*** *mult* = **.72***	*adj* = **.64*** *mult* = **.87***	*adj* = **.63*** *mult* = **.82***	*adj* = .56 *mult* = .78
Angle	34	*adj* = .10 *mult* = .19	*adj* = **.51*** *mult* = **.63***	*adj* = **.38*** *mult* = **.53***	*adj* = .49 *mult* = .68	*adj* = .28 *mult* = .73	*adj* = .42 *mult* = .77	*adj* = **.67*** *mult* = **.83***
comparison model:		*null*	*Baseline*				*Quality Ranking *Baseline*	

Note. All models include age and gender and their interactions as covariates of no interest. Baseline models additionally include the Cube Quality Ranking (QR) score. All models include all interactions. Asterisks indicate statistical significance at '*' $p < 0.05$.

1 ***Findings suggest an association between the fine motor skills used in paper folding and the dexterity required to hold and control a marker/pen while drawing.***

2 ***Contemporary methods increase ability to predict latent structure in children's drawings.***

References

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