

**Appendix 1.** Table on visualization challenges

**Table A1.1.** Details supporting the assessment of visualization types according to the specific aspects of the challenges presented and explained in Section 2 in the main text. No entries denote that the visualization type is, to our knowledge, typically not used to address the respective aspect of the challenge. Categories for overall assessment: **o** Cannot meet the challenge. **✓** Can partly meet the challenge, requires specific adjustments. **✓✓** Broadly meets the challenge. **✓✓✓** Is especially suited to meet the challenge (cf. Table 1).

Visualization challenge	Specific aspect of the challenge	Objects and arrows			X-Y-plots	X-Y-Z-plots
		Conceptual diagrams	Causal diagrams	Network diagrams		
1 Visualizing whether a relationship is causal	Discriminating causation from mere covariance	suitable	suitable	possible (only for potential causal relationships, excludes causation when no connection)		
	Confounding	suitable	suitable	conceivable (for potential confounding)		
<i>Overall assessment</i>		<b>✓✓✓</b>	<b>✓✓✓</b>	<b>✓</b>	<b>o</b>	<b>o</b>
2 Visualizing the characteristics of causal relationships	Discriminating positive from negative relationships	possible (arrow labels)	suitable (e.g. +/- labels)		suitable	suitable
	Strength of relationships	possible (arrow styles)	possible (e.g. SEM path coefficients)	possible (weighted edges)	suitable	suitable
	Shape of relationships (incl. nonlinearity, discontinuities)				suitable	suitable (discerning exact shapes can be difficult)
<i>Overall assessment</i>		<b>✓</b>	<b>✓</b>	<b>✓</b>	<b>✓✓✓</b>	<b>✓✓</b>

Visualization challenge	Specific aspect of the challenge	Objects and arrows			X-Y-plots	X-Y-Z-plots
		Conceptual diagrams	Causal diagrams	Network diagrams		
3 Visualizing reciprocal causal relationships	Feedback	suitable	suitable	possible (only for potential feedback)	possible (phase space plot)	possible (phase space plot)
	Hysteresis				possible	possible
	Cyclic dynamics		possible (e.g. causal loop diagrams)		possible (e.g. phase space plot)	possible (e.g. phase space plot)
<i>Overall assessment</i>		✓	✓✓	✓	✓✓	✓
4 Visualizing multiple causes	Equifinality	suitable	suitable			suitable (two causes)
	Moderation, context-dependence	conceivable (e.g. arrows pointing at arrows)				suitable
	Emergence	possible (e.g. arrow labels)				suitable (for emergence from interactions of two causes)
	Discriminating direct from indirect relationships, different resolutions of system elements	suitable	suitable	possible (only for potential relationships)		
<i>Overall assessment</i>		✓✓	✓	o	o	✓✓

Visualization challenge	Specific aspect of the challenge	Objects and arrows			X-Y-plots	X-Y-Z-plots
		Conceptual diagrams	Causal diagrams	Network diagrams		
5 Visualizing temporal dynamics of causal relationships	Change of relationships over time					possible (time as one axis)
	Path dependence, legacy effects	conceivable (diagram of potential system states)		conceivable (network of potential system states)	possible (phase space plot)	
	Delayed effects				possible (events marked in time series)	possible (time as one axis)
	Effects of events and interventions	possible (temporal sequence of events, e.g. flowcharts)	conceivable (events as objects)		possible (e.g. marked in time series)	possible (time as one axis)
<i>Overall assessment</i>		✓	○	✓	✓	✓✓
6 Visualizing uncertainty about causal relationships	Uncertainty about causation	conceivable (e.g. arrow styles, labels)				
	Stochastic relationships	possible (e.g. arrow styles, labels)	possible (strength of statistical relationship for SEM)		suitable (e.g. error bars, intervals, labels for statistical test results)	possible (e.g. point clouds, labels for statistical test results)
<i>Overall assessment</i>		✓	○	○	✓✓	✓