

Hybrid touch/tangible Spatial 3D data selection



Lonni Besançon, Mickael Sereno, Linyun Yu, Mehdi Ammi, Tobias Isenberg

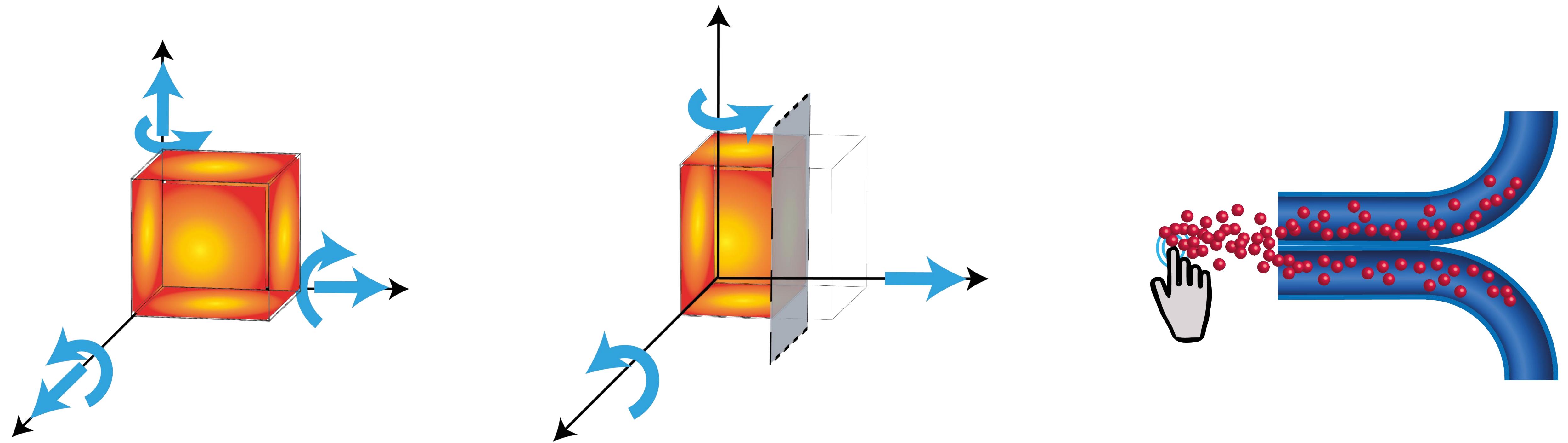


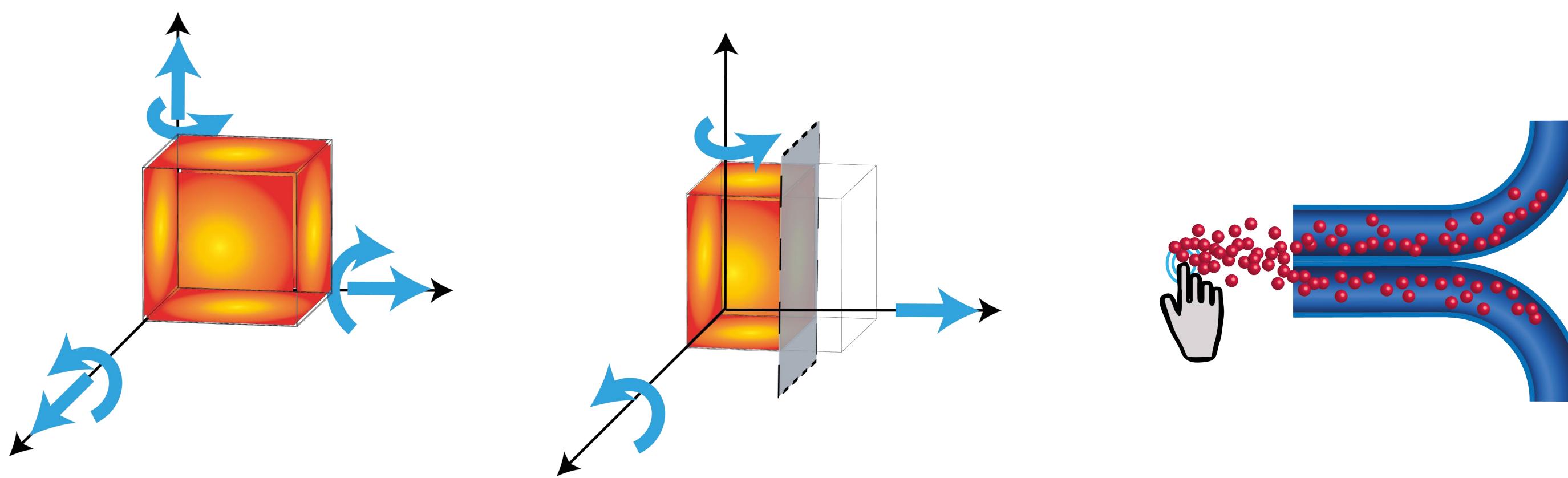
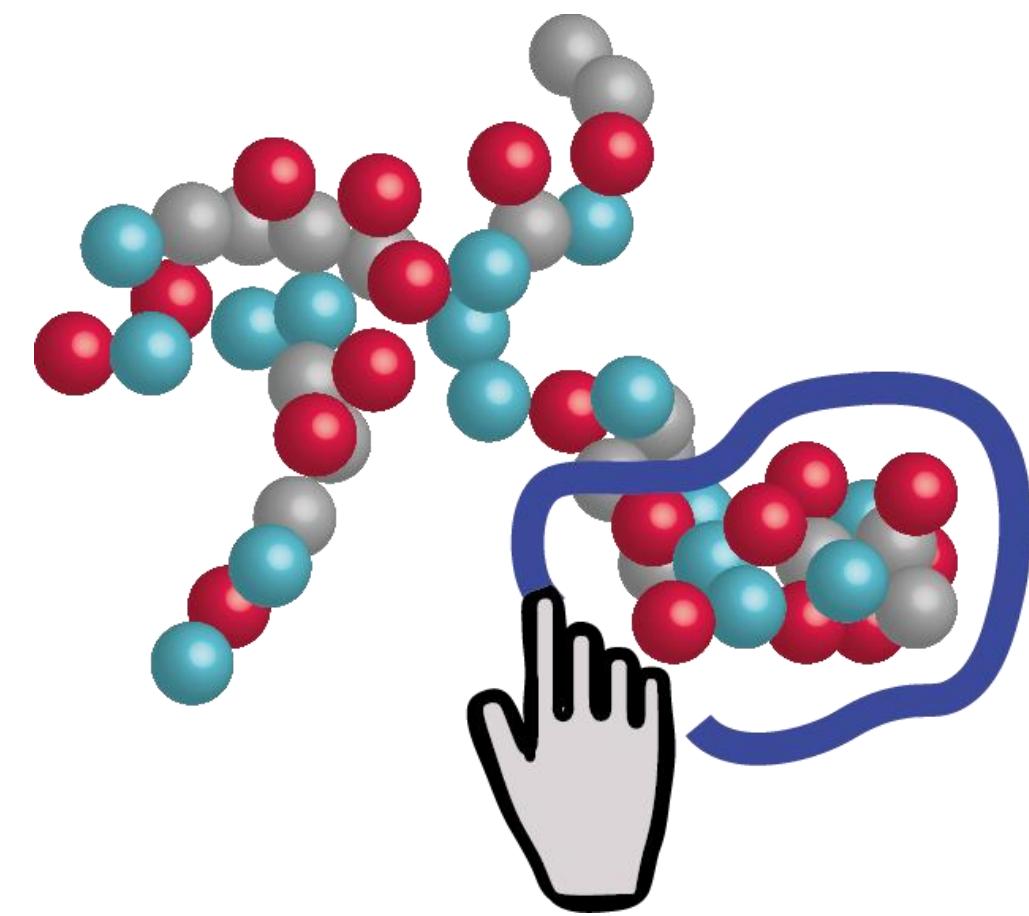
@lonnibesancon



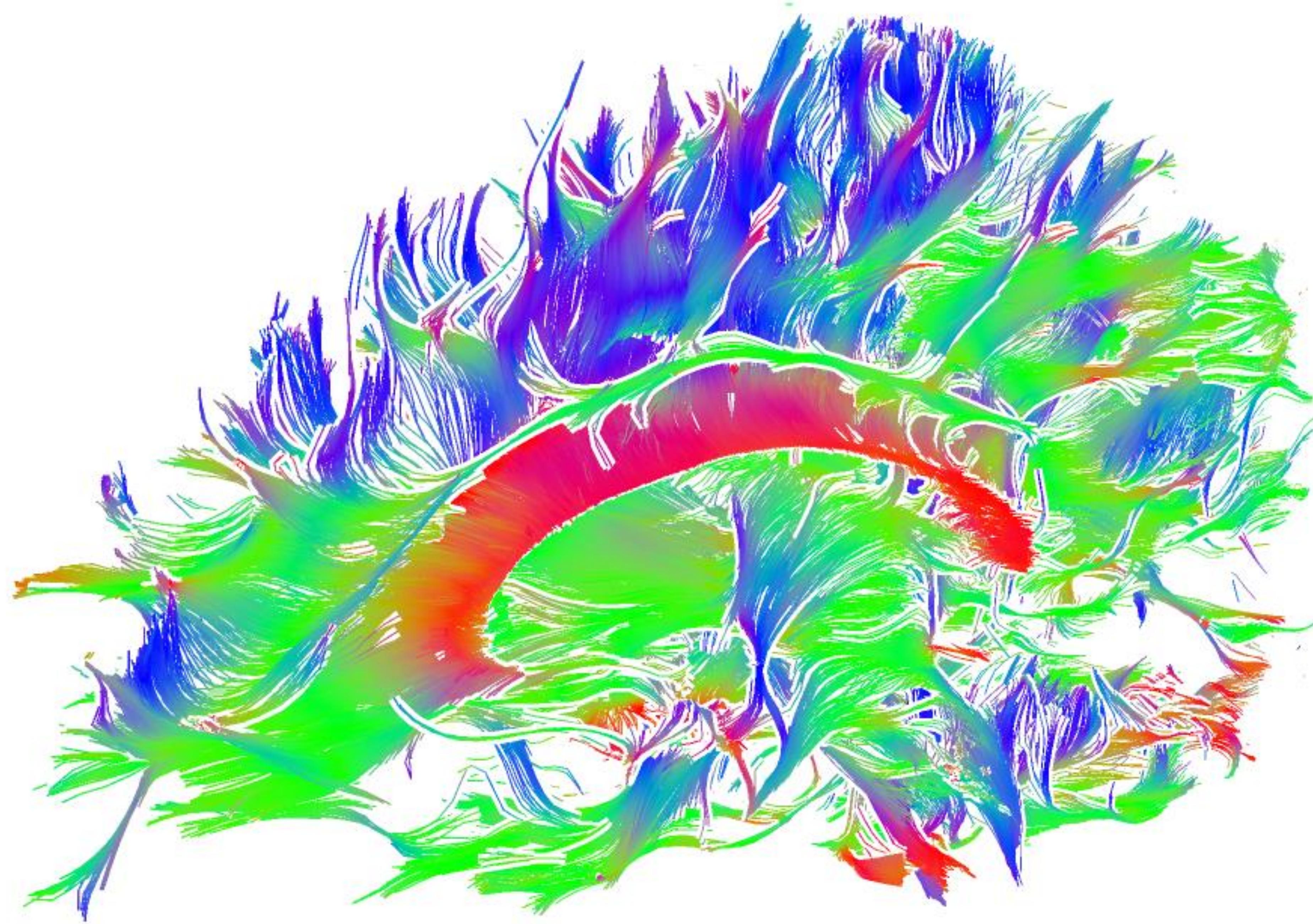
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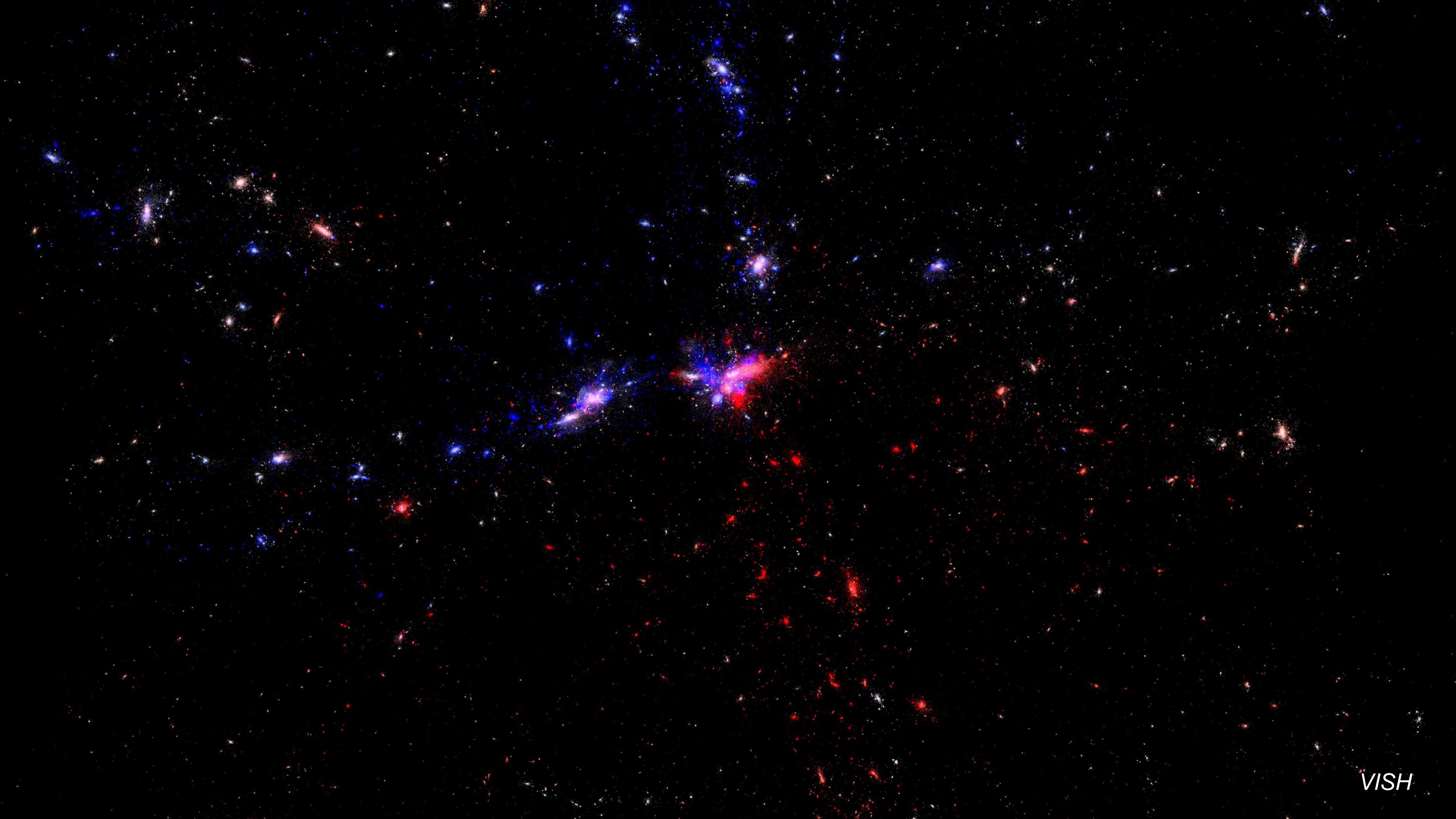










A wide-field image of the universe, showing a vast number of galaxies of various sizes and colors. The most prominent feature is a large, luminous cluster of galaxies in the center-left, appearing in shades of blue, purple, and red. The background is a deep black, filled with smaller, fainter galaxies scattered across the frame.

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Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBW96]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6 DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6 DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
SenseShapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom.	2D input	no control	2 DOF	2 DOF
CloudLasso [YEI12]	lasso	ROI	semi-autom.	2D input	threshold adjust.	2 DOF	2 DOF
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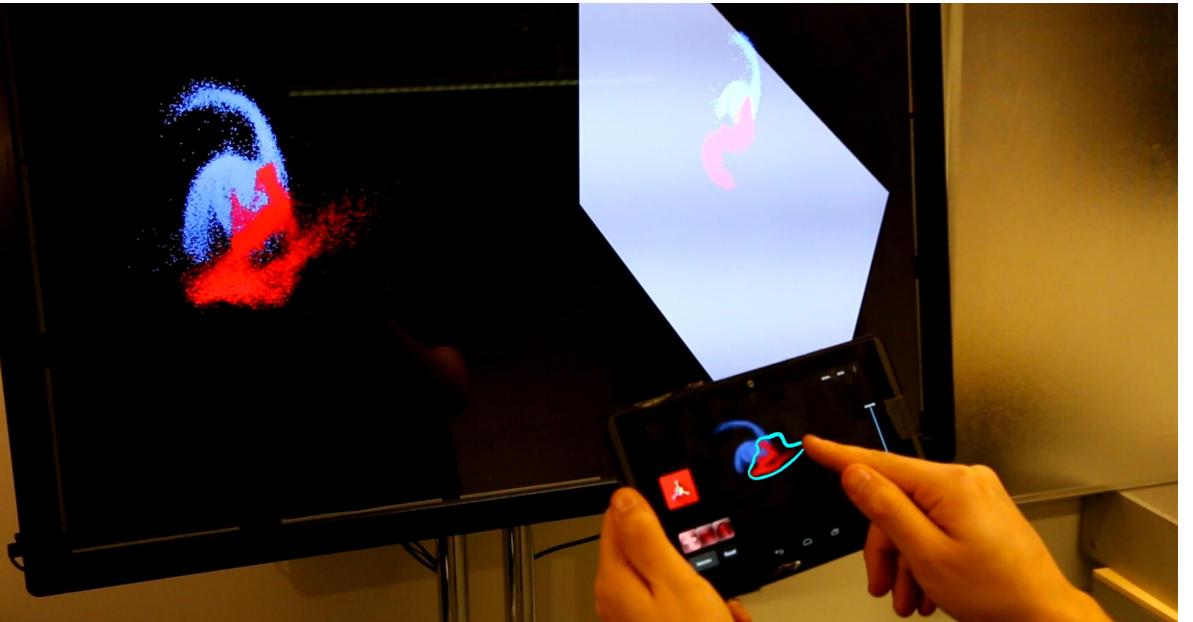


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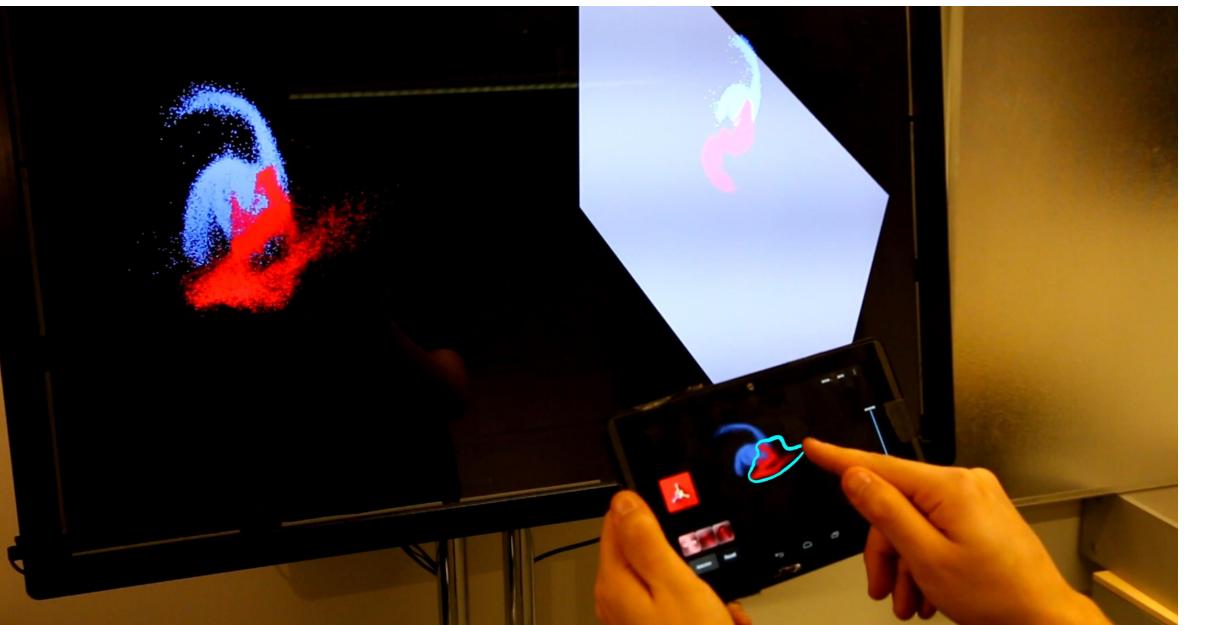


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Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual

Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

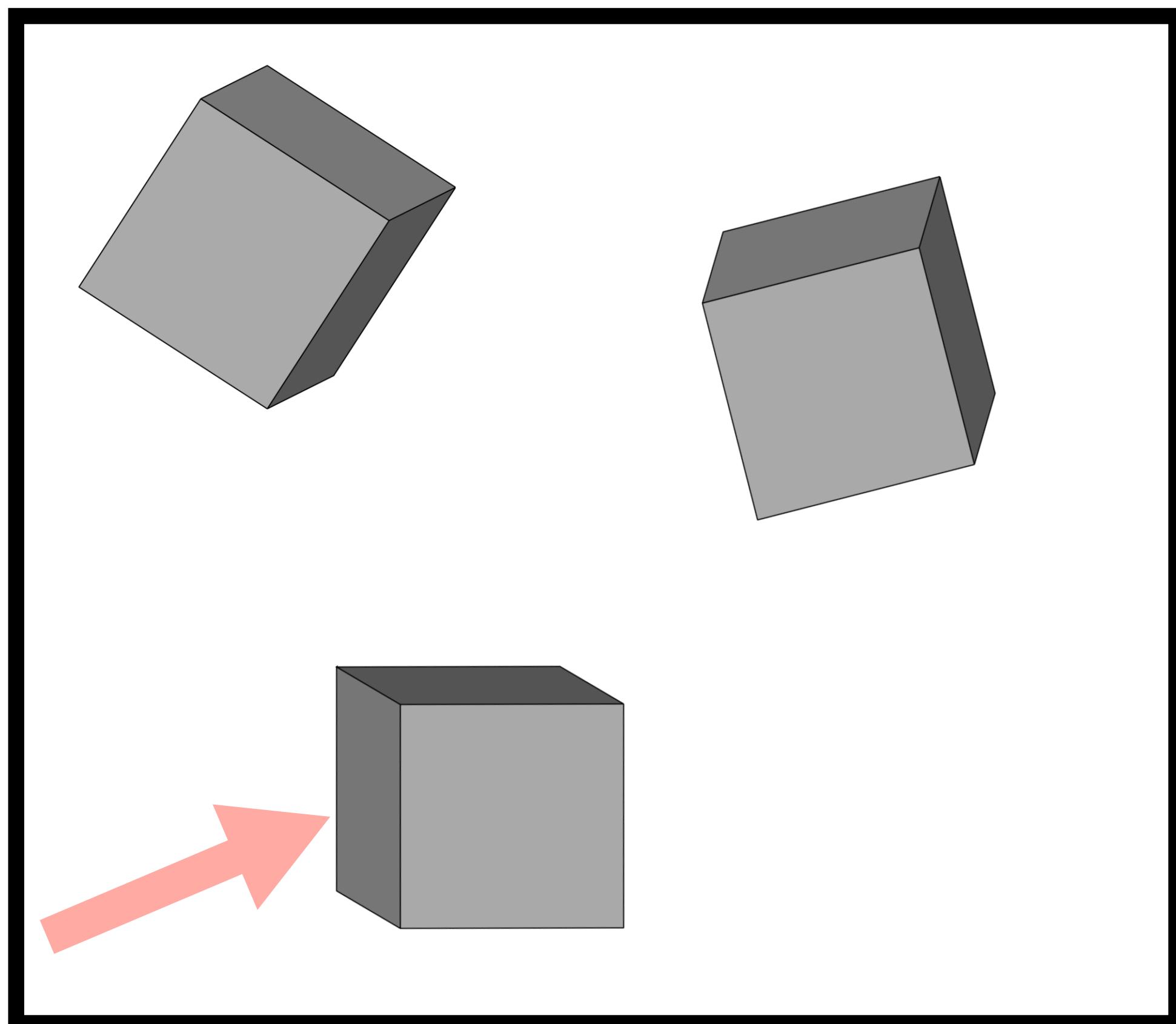
technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBWI96]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual

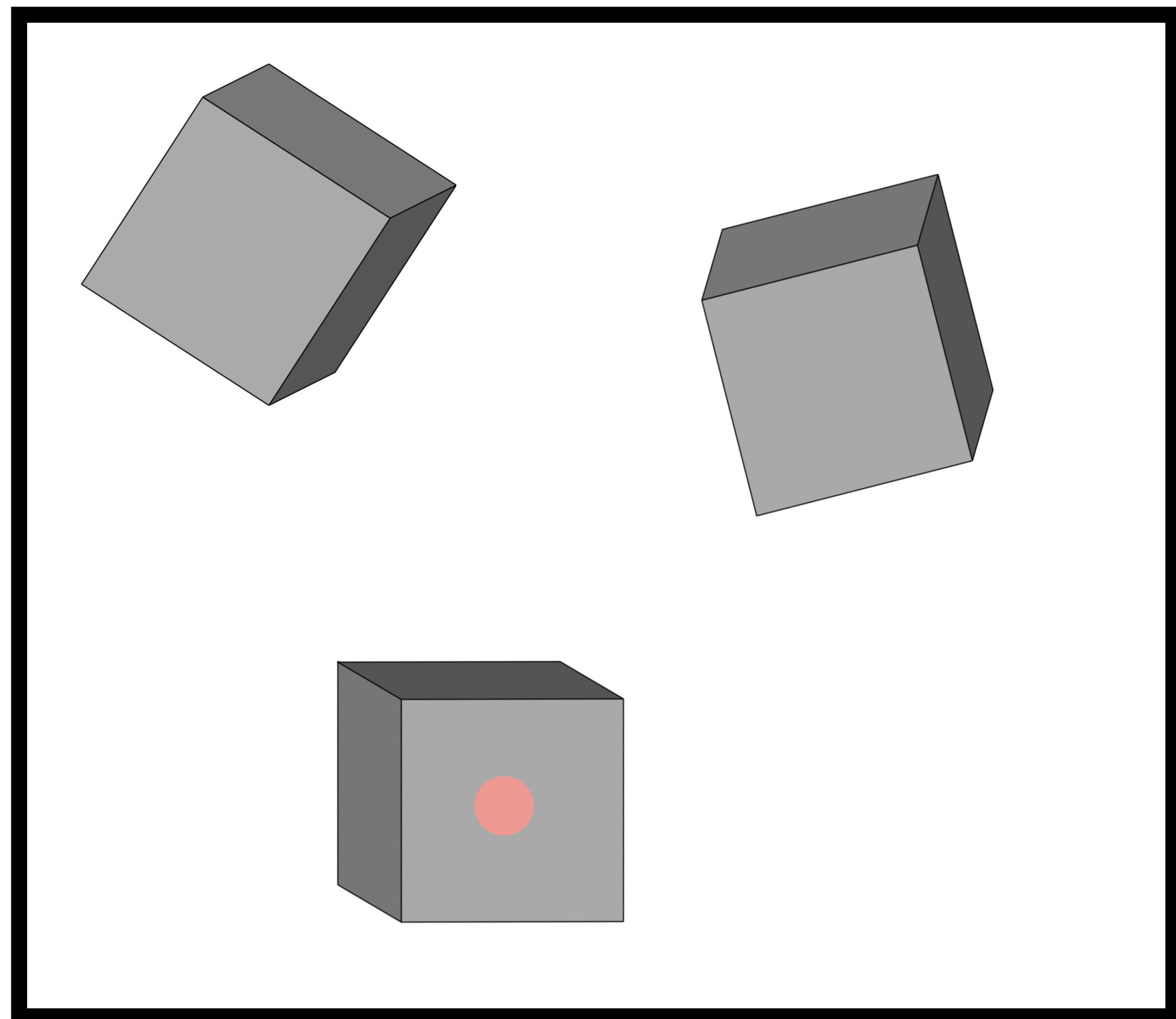
Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

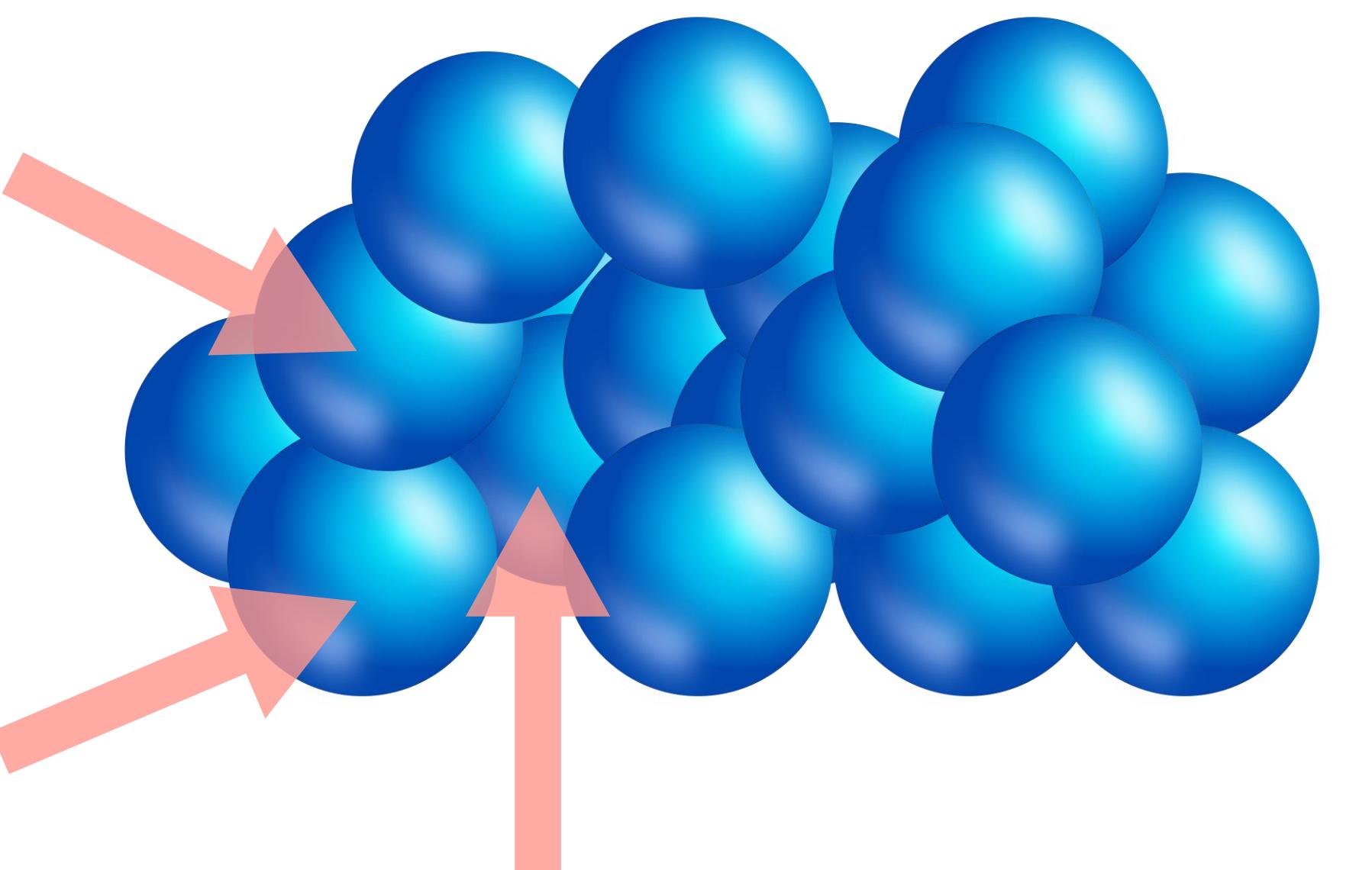
technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBWI96]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual

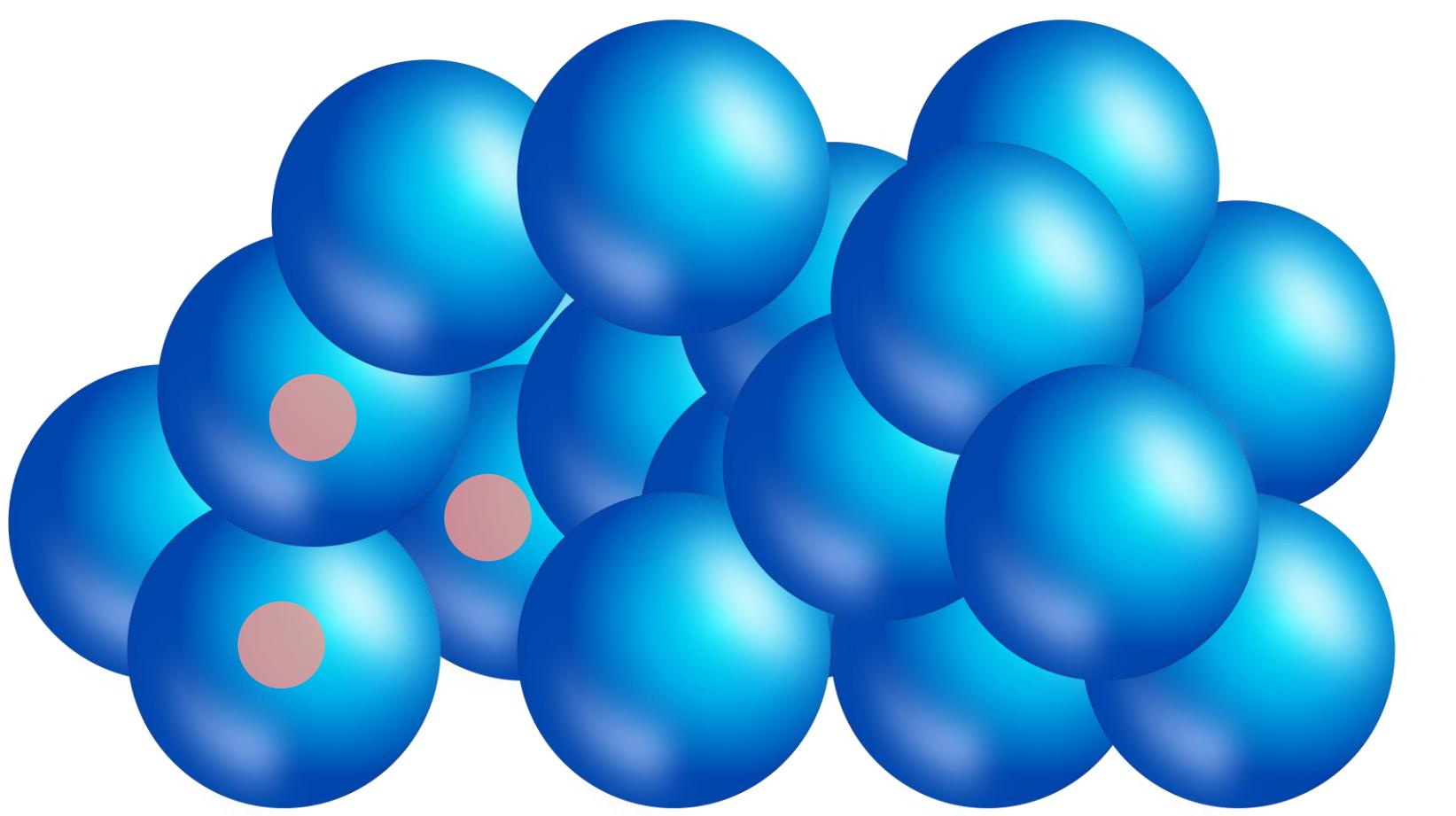
Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

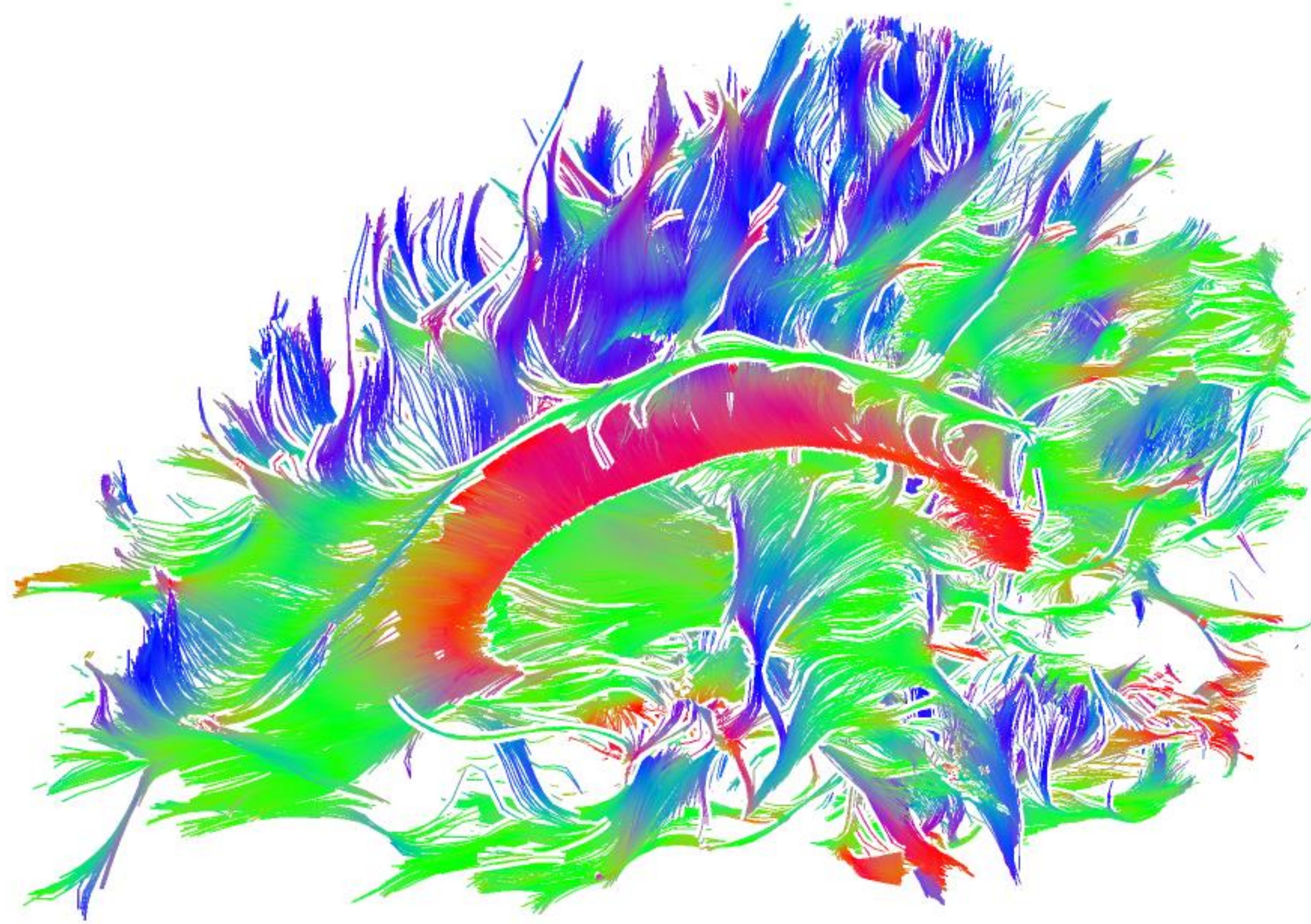
technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBWI96]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual



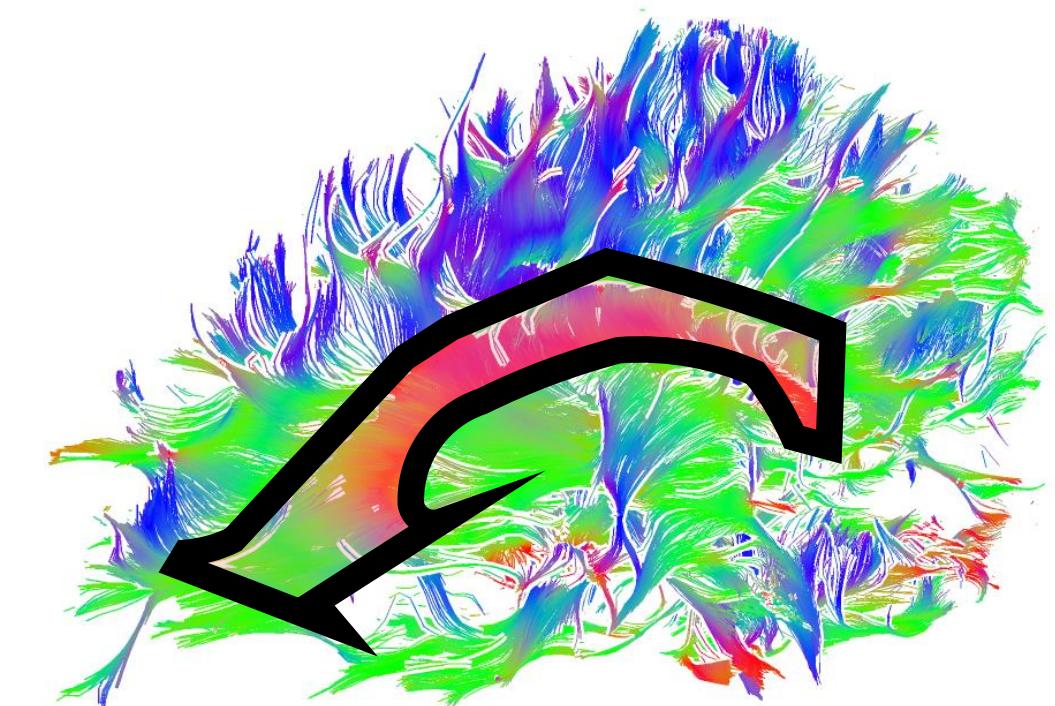
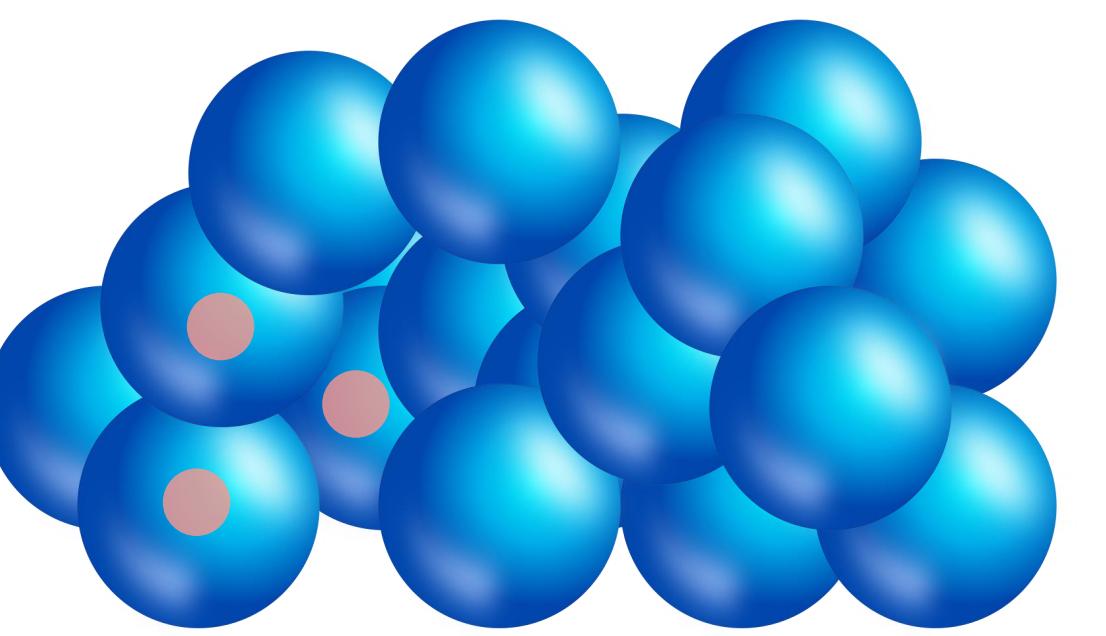
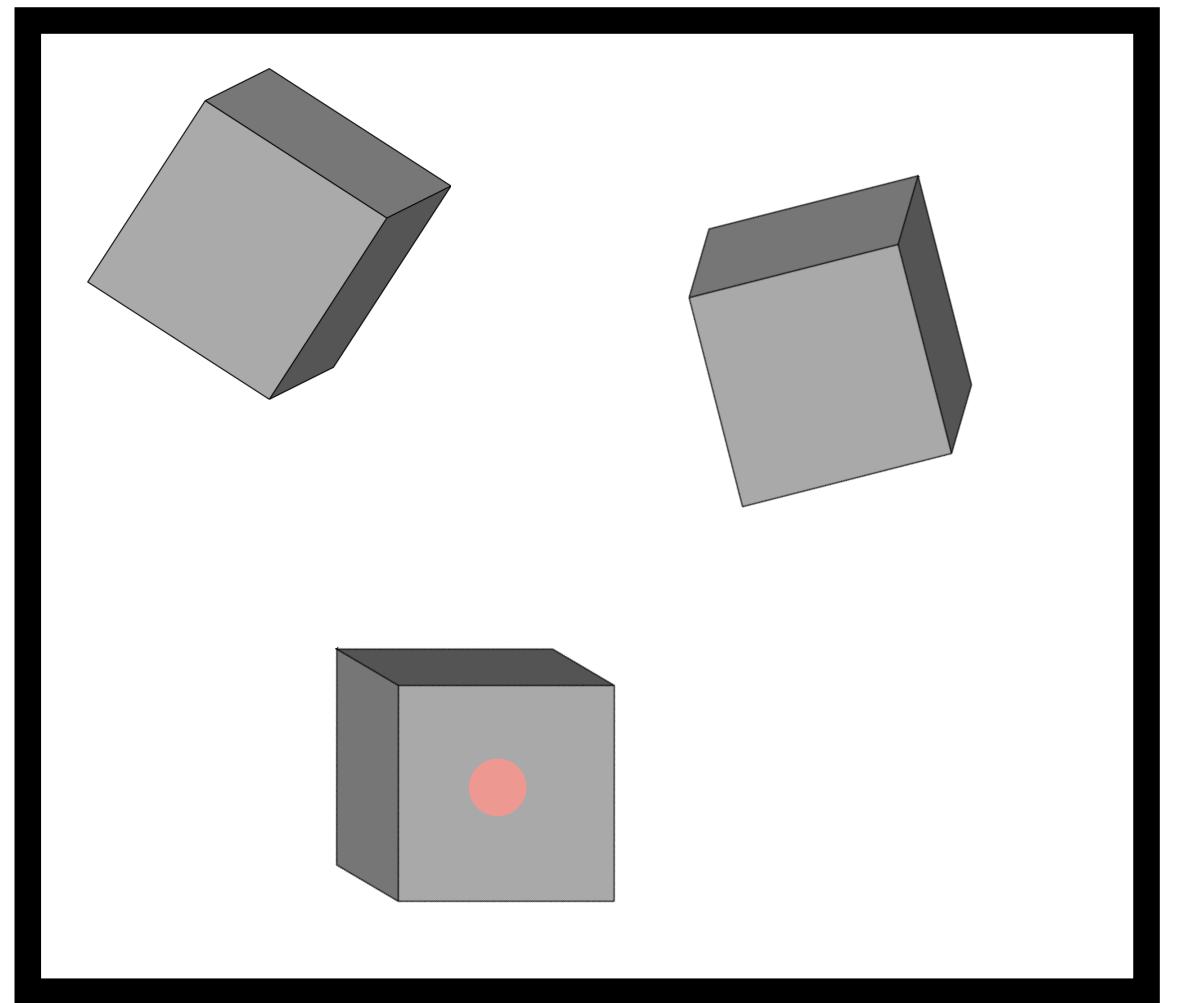




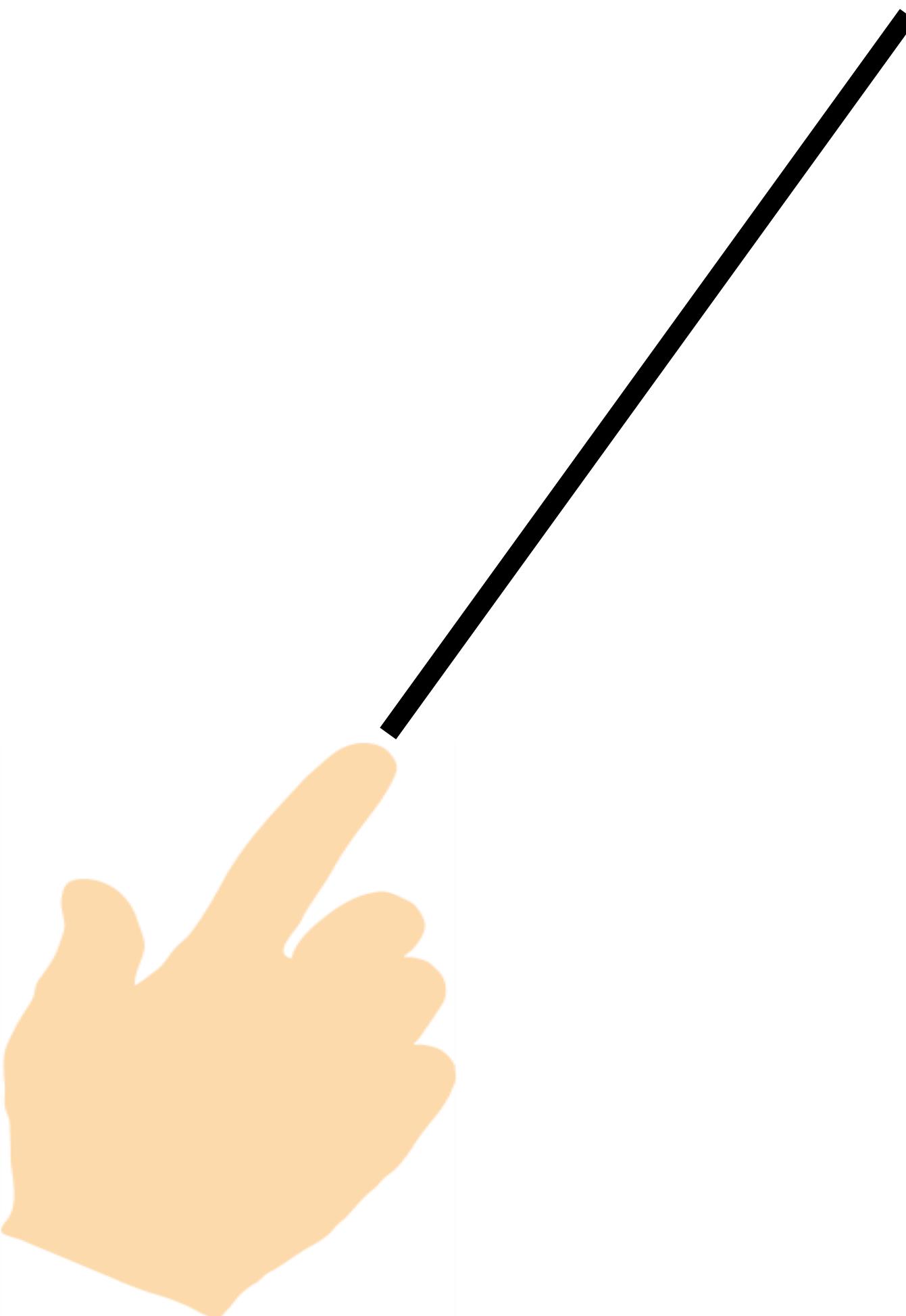




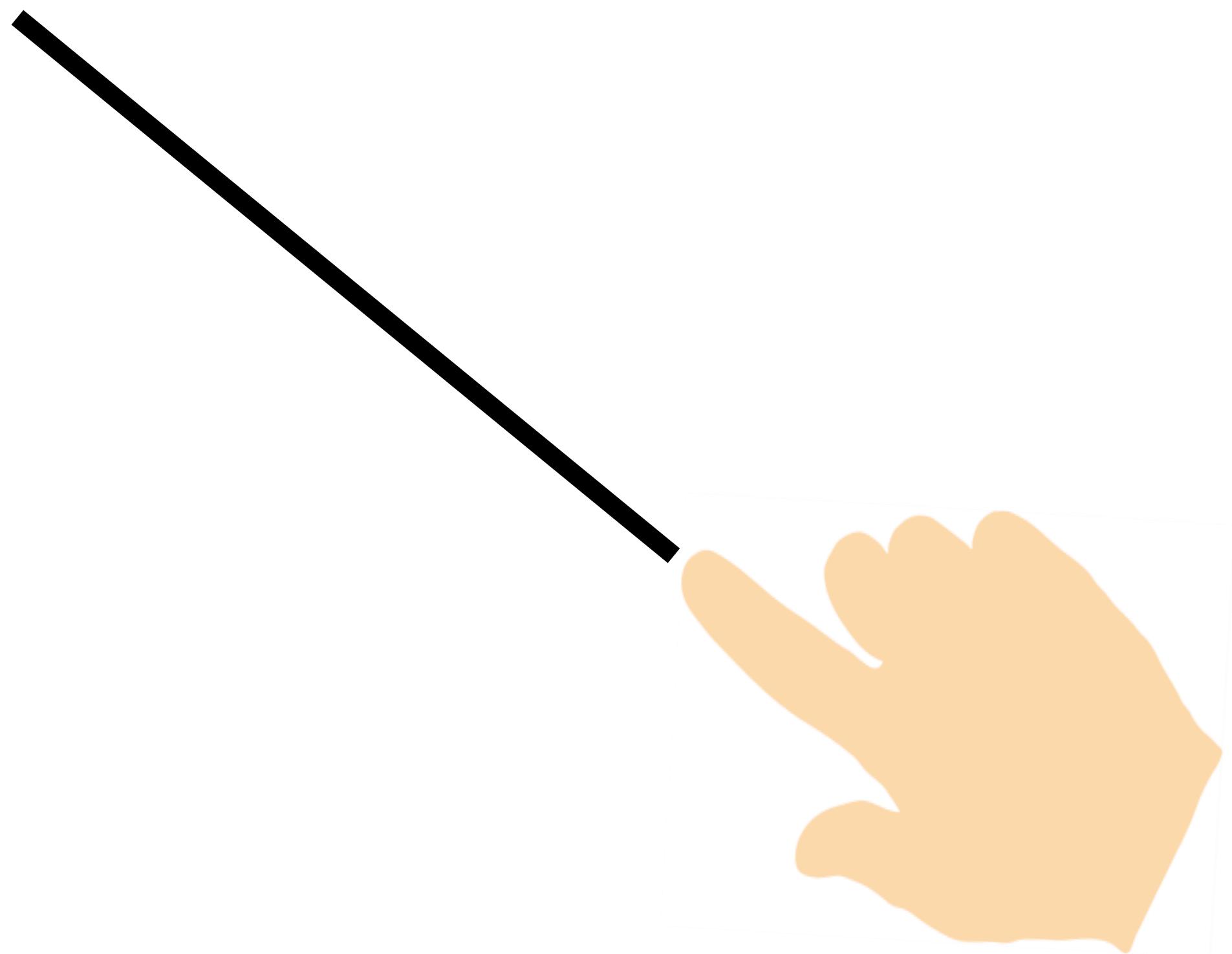




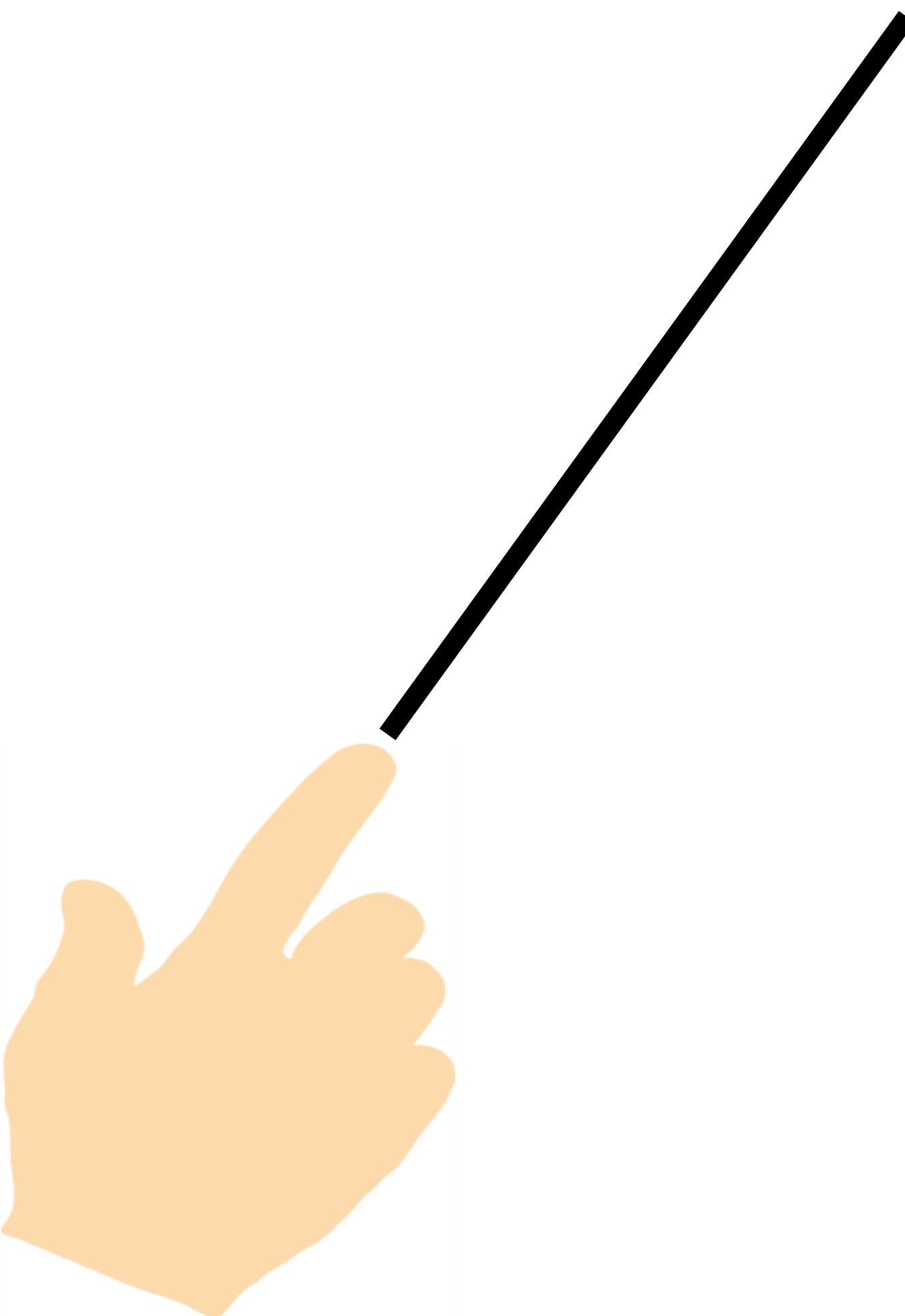
Ray Casting

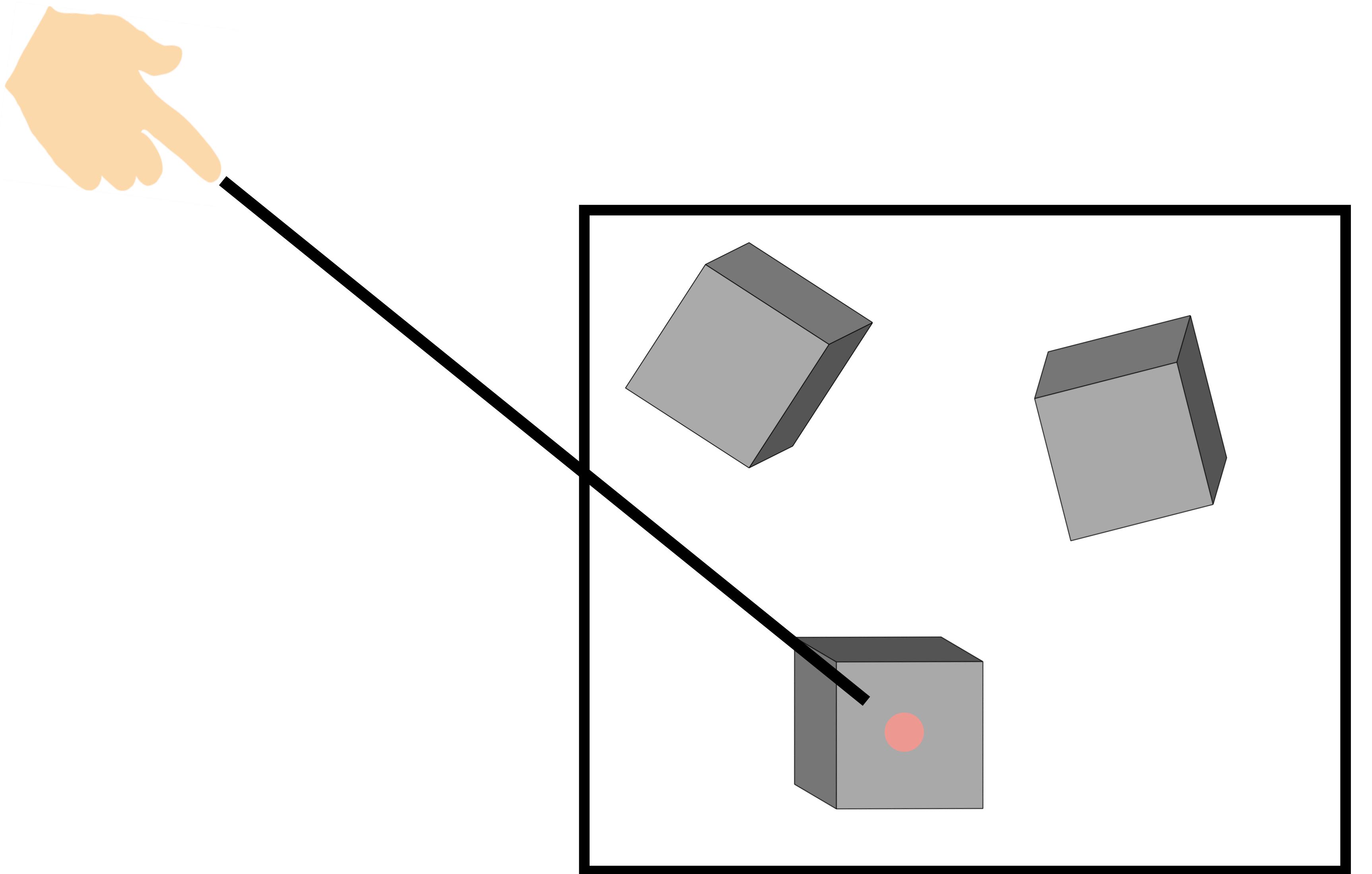


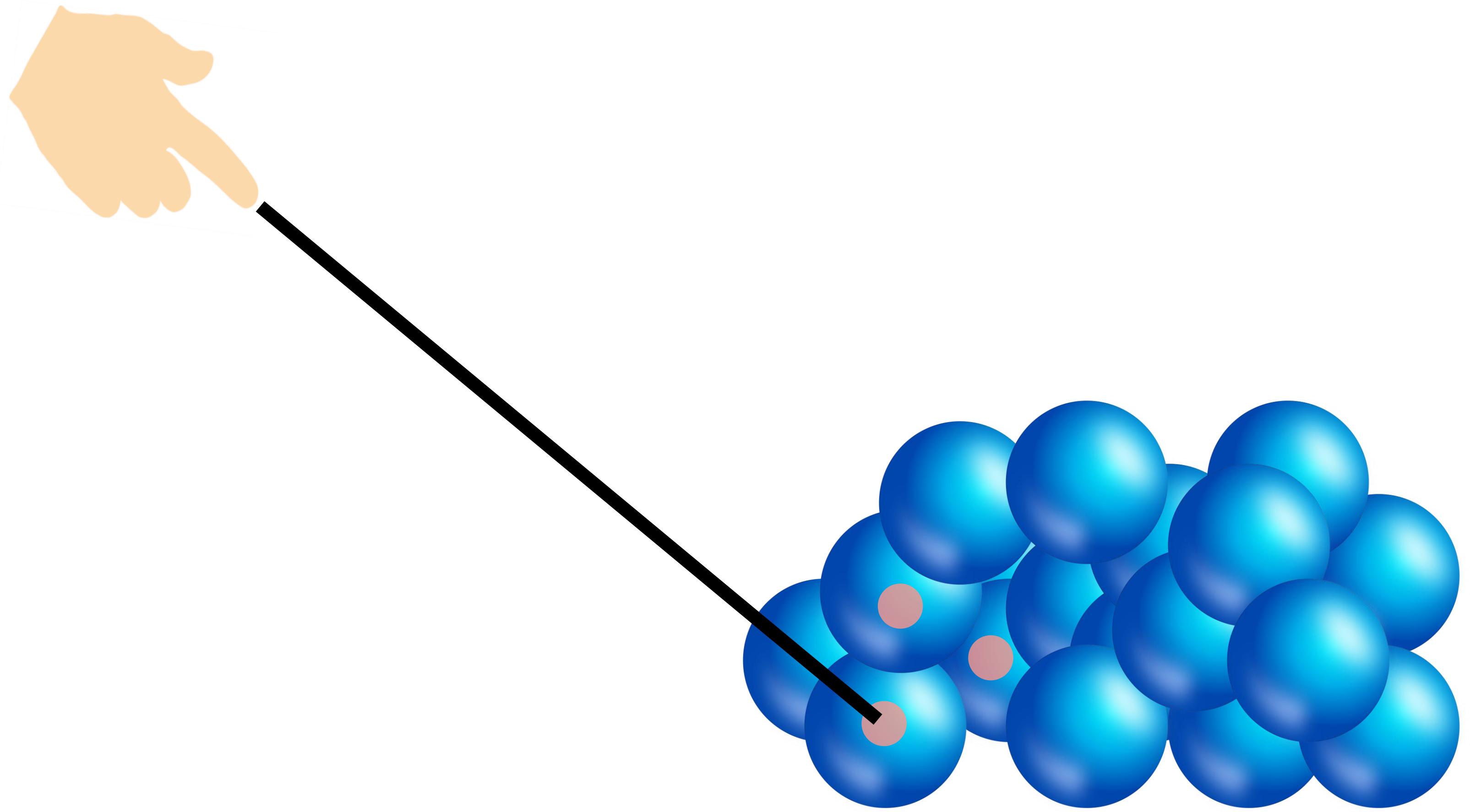
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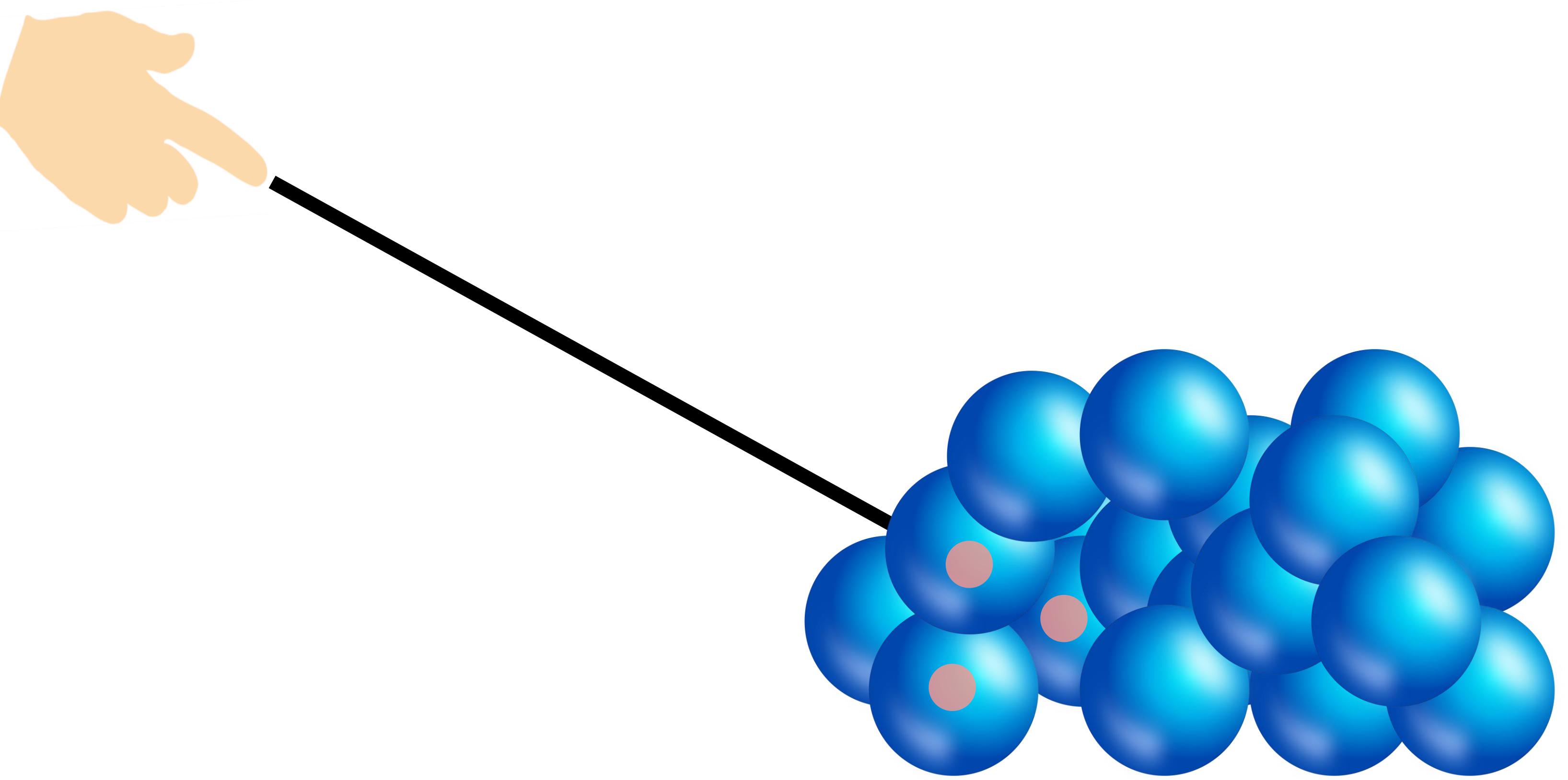


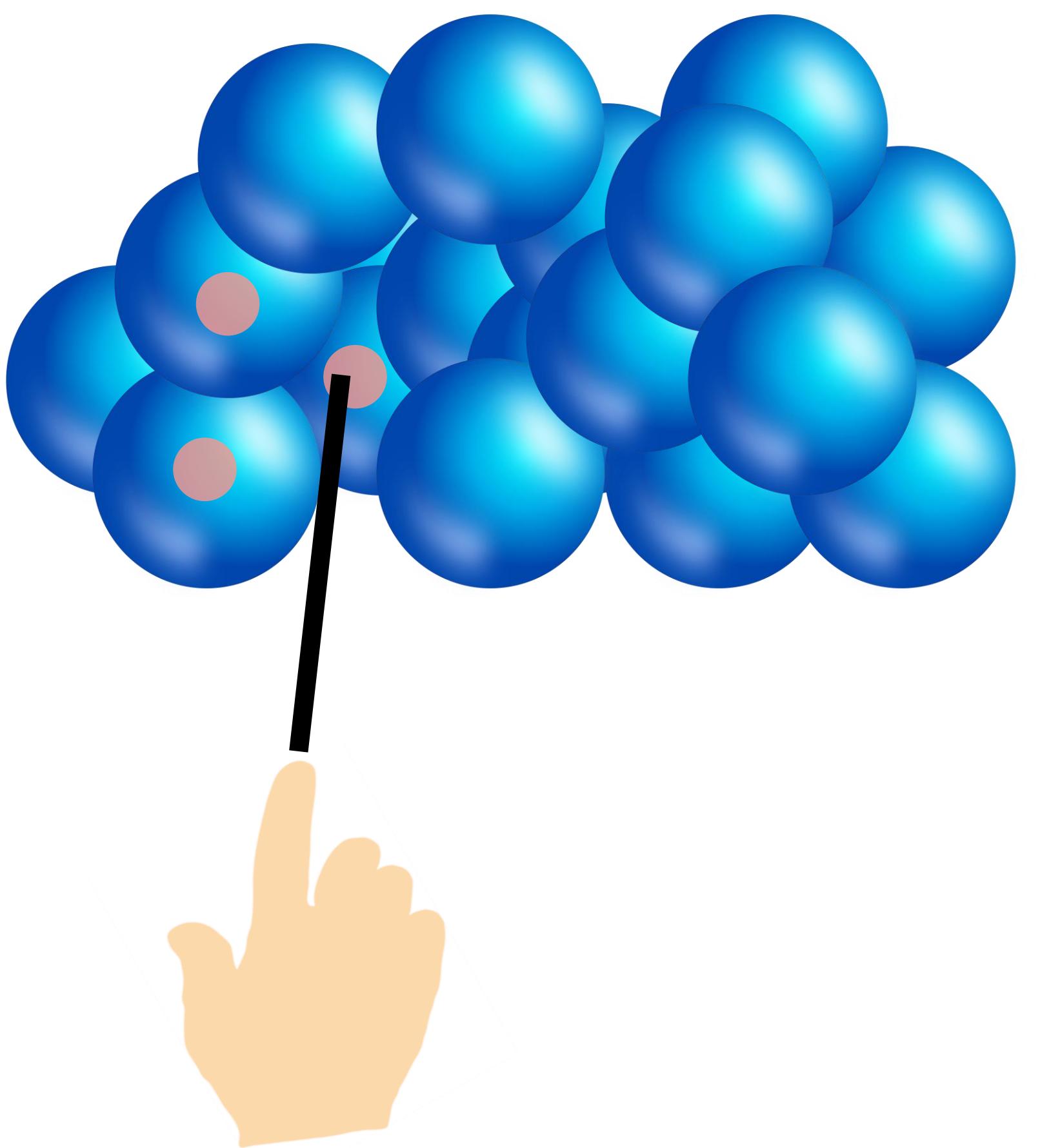
Ray Casting

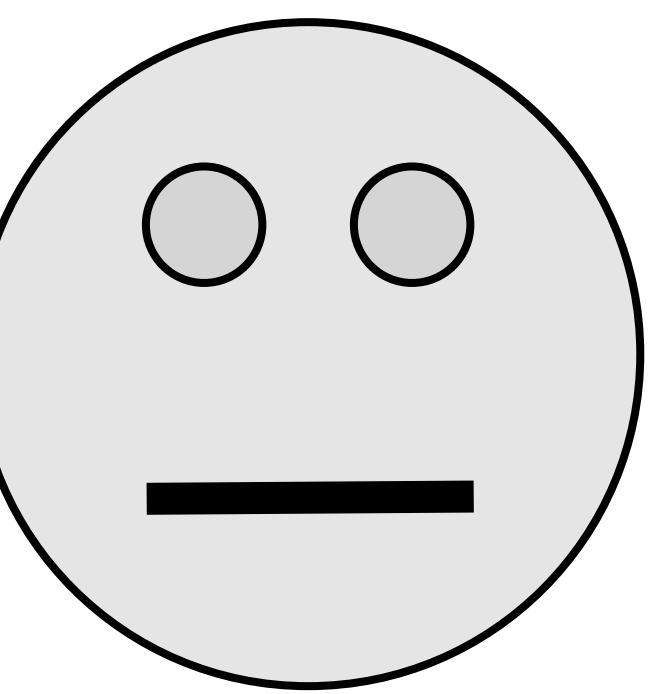
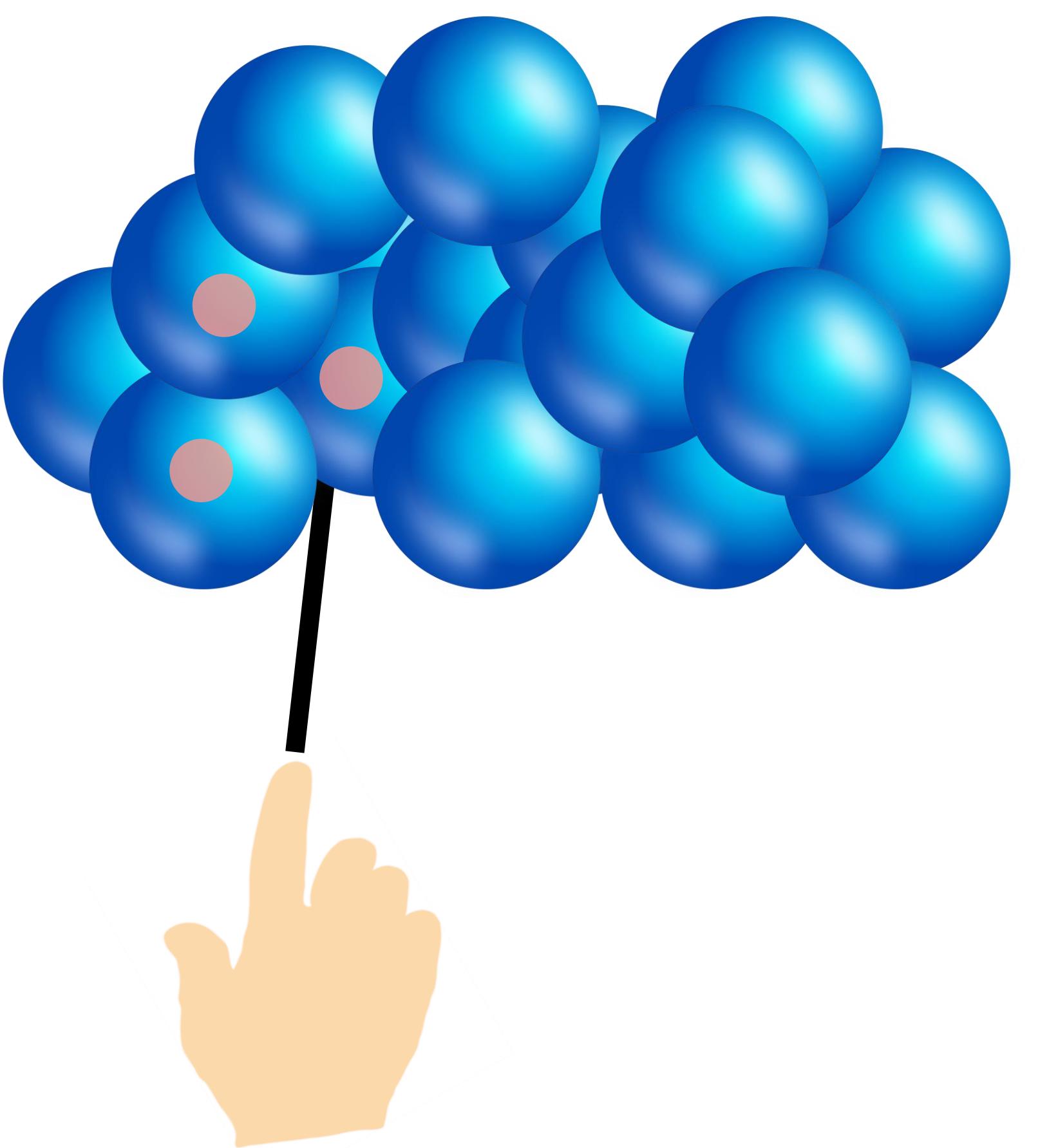


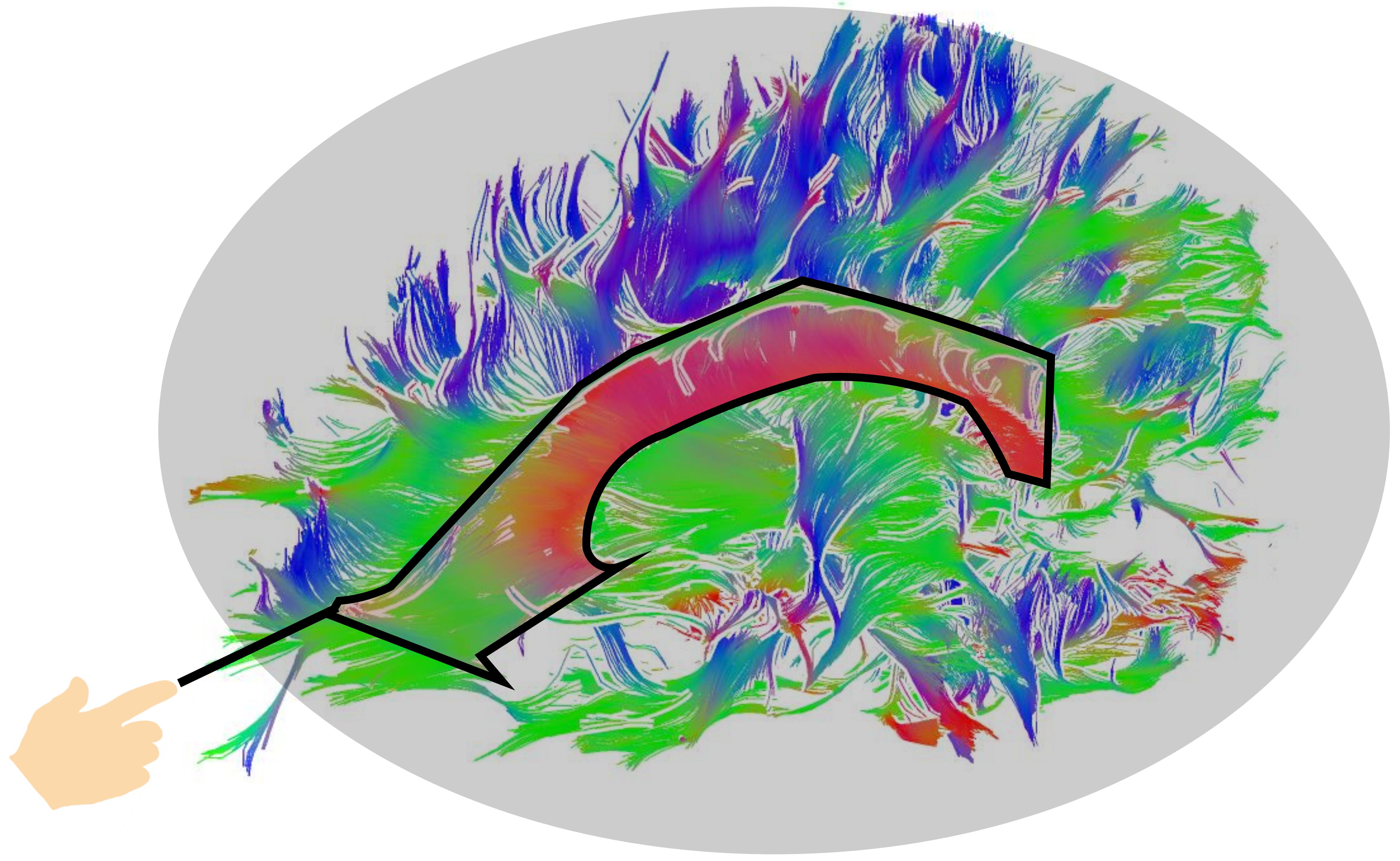


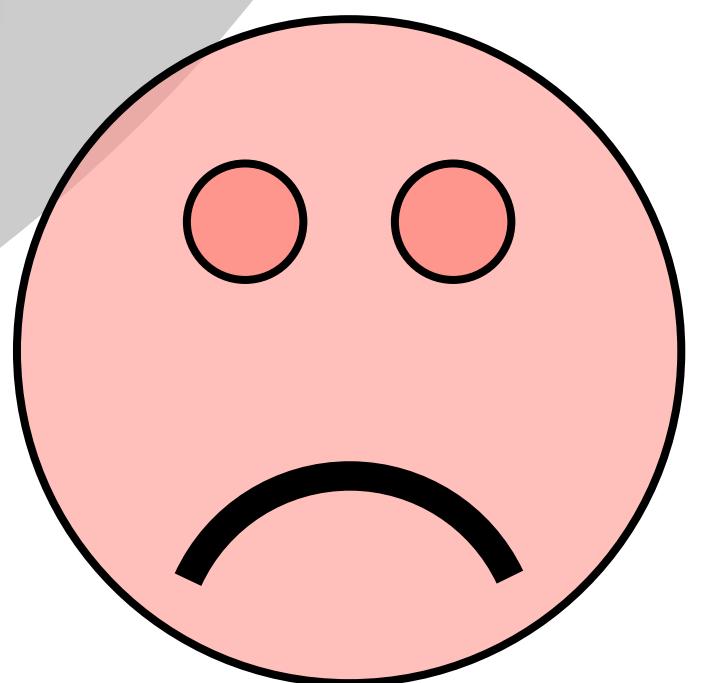
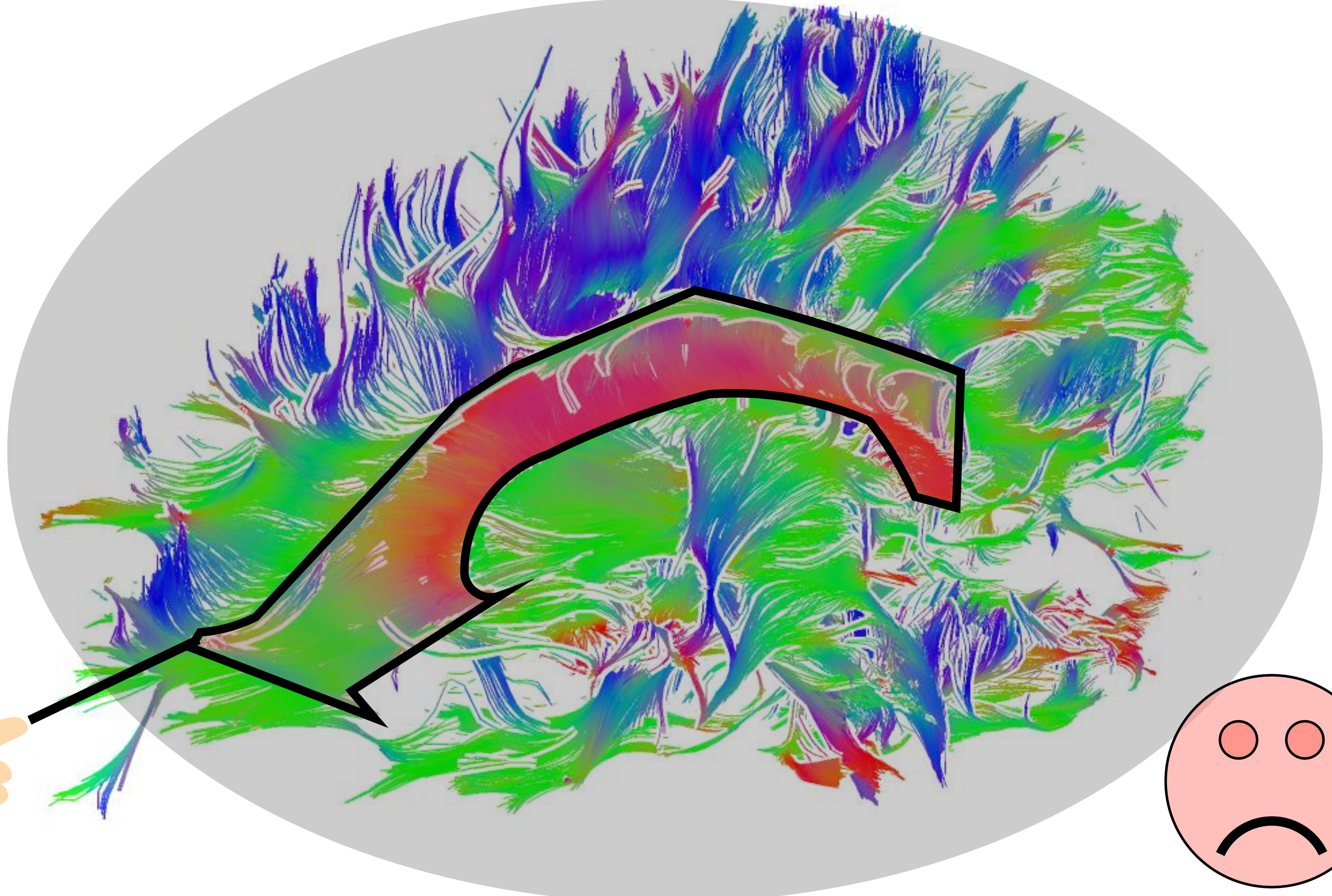
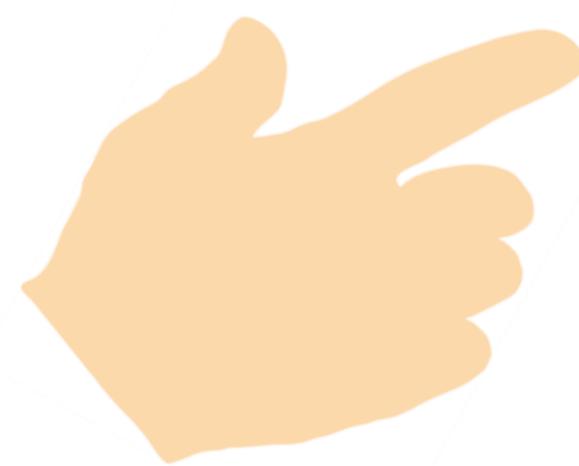




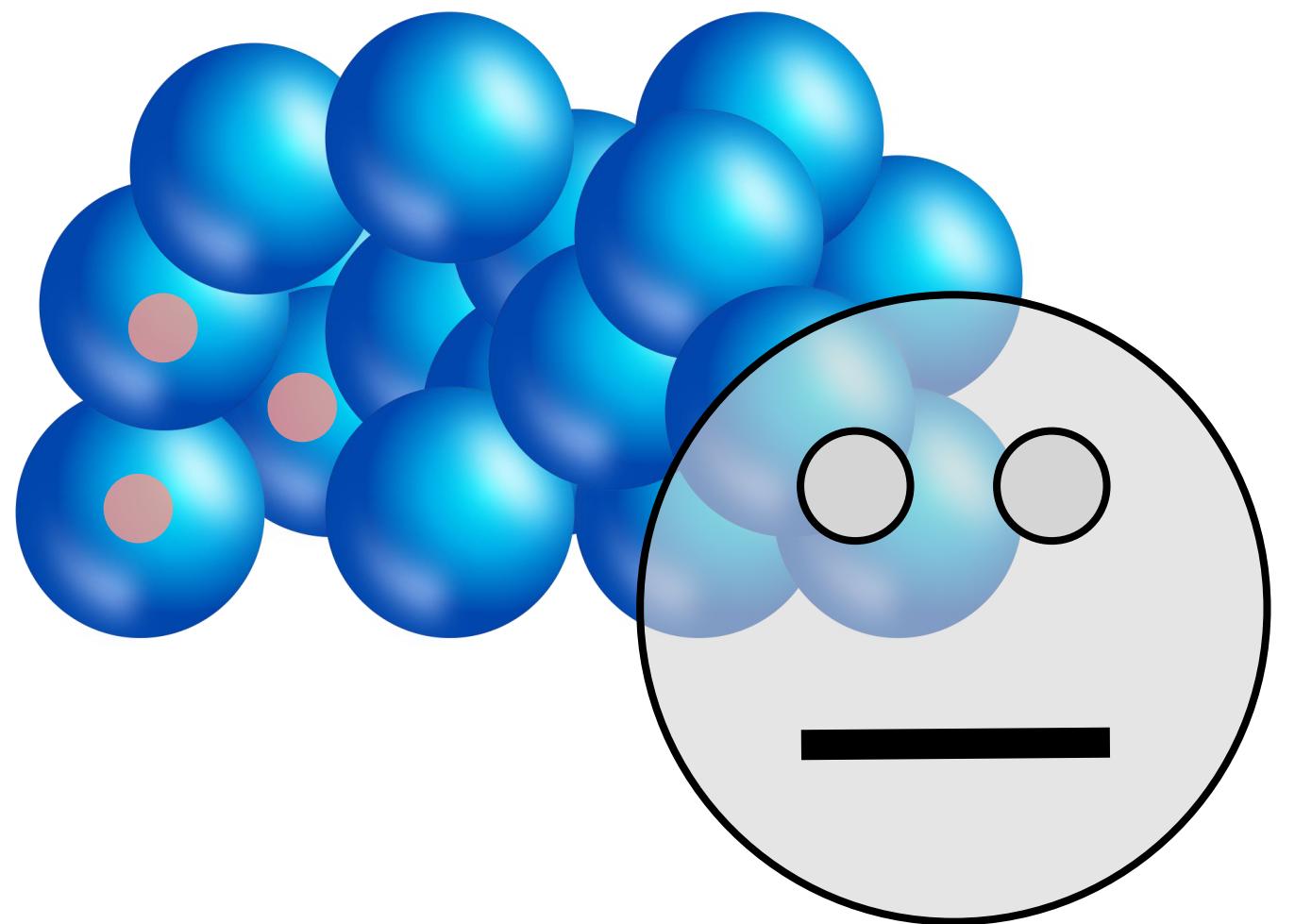
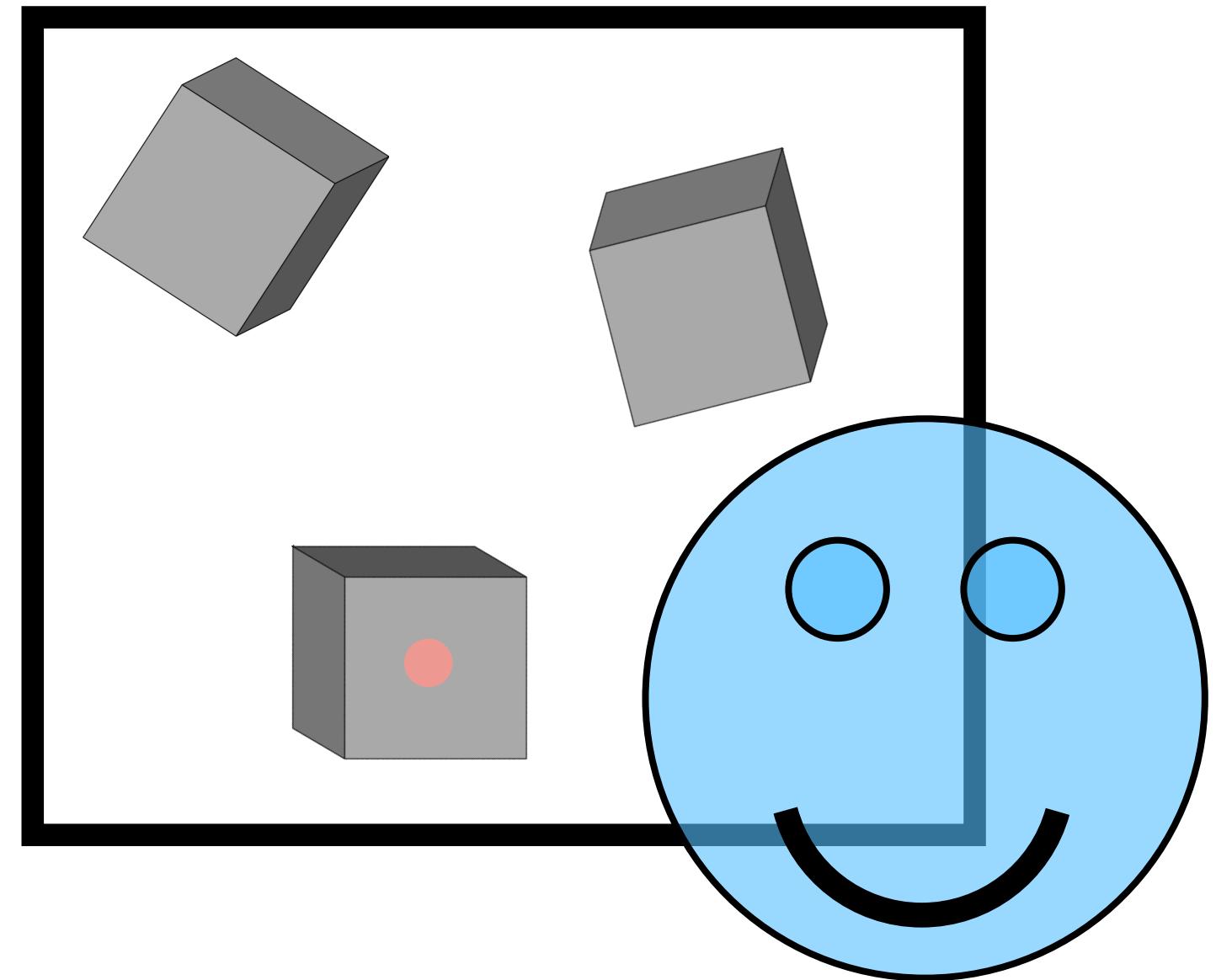




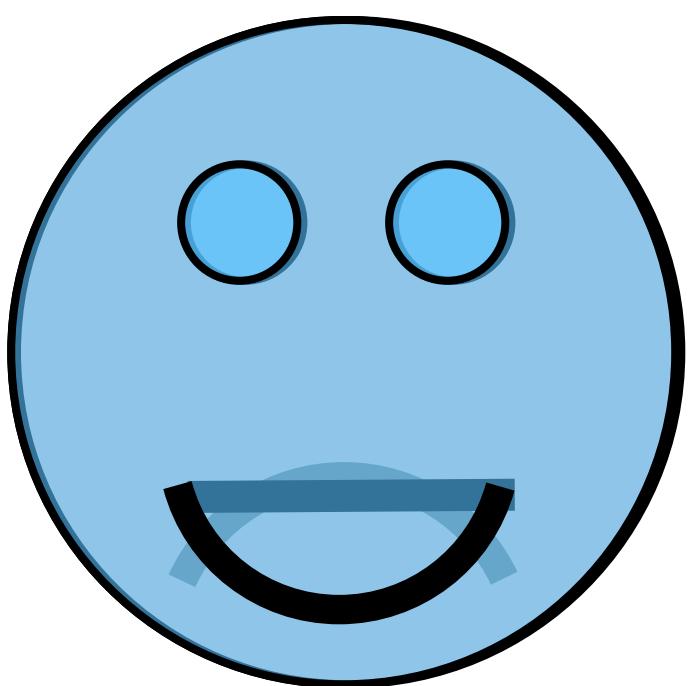




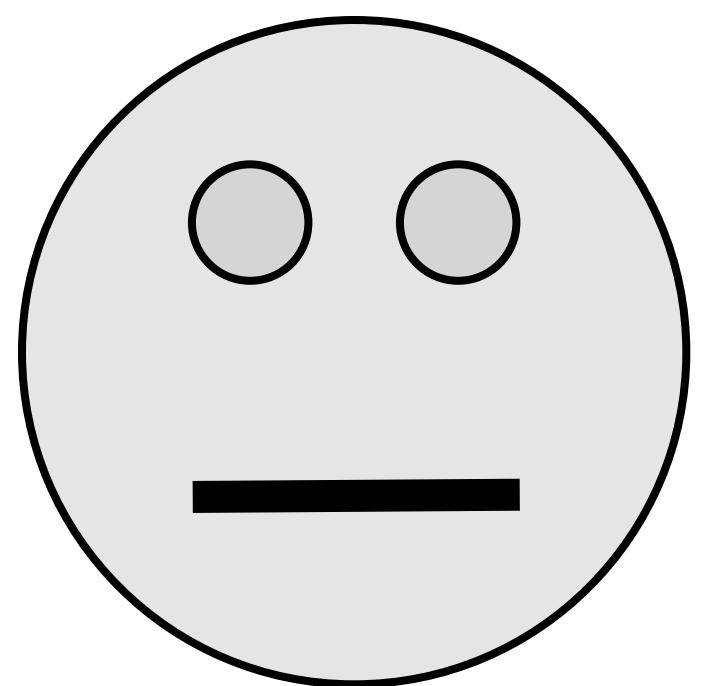
Ray Casting



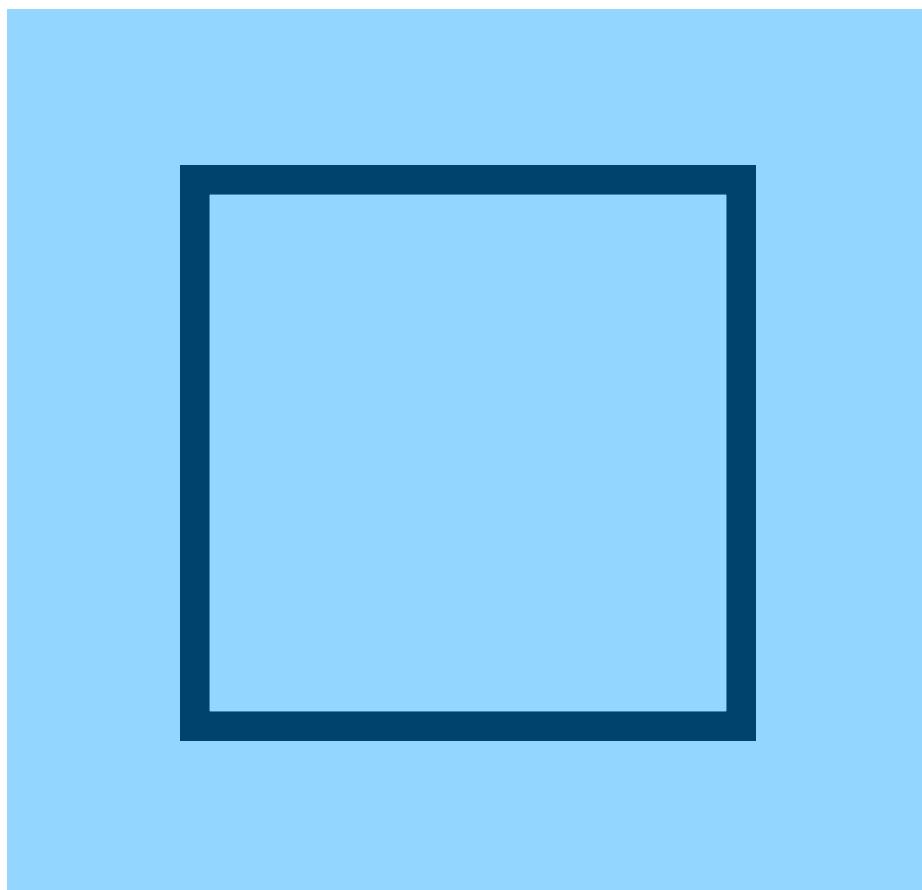
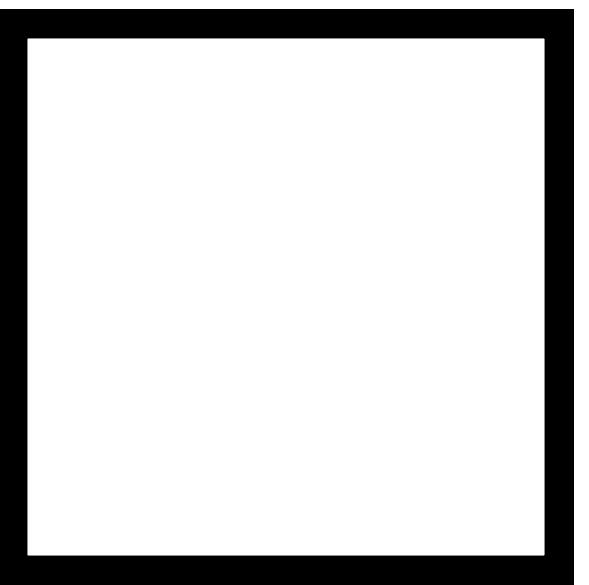
Ray Casting

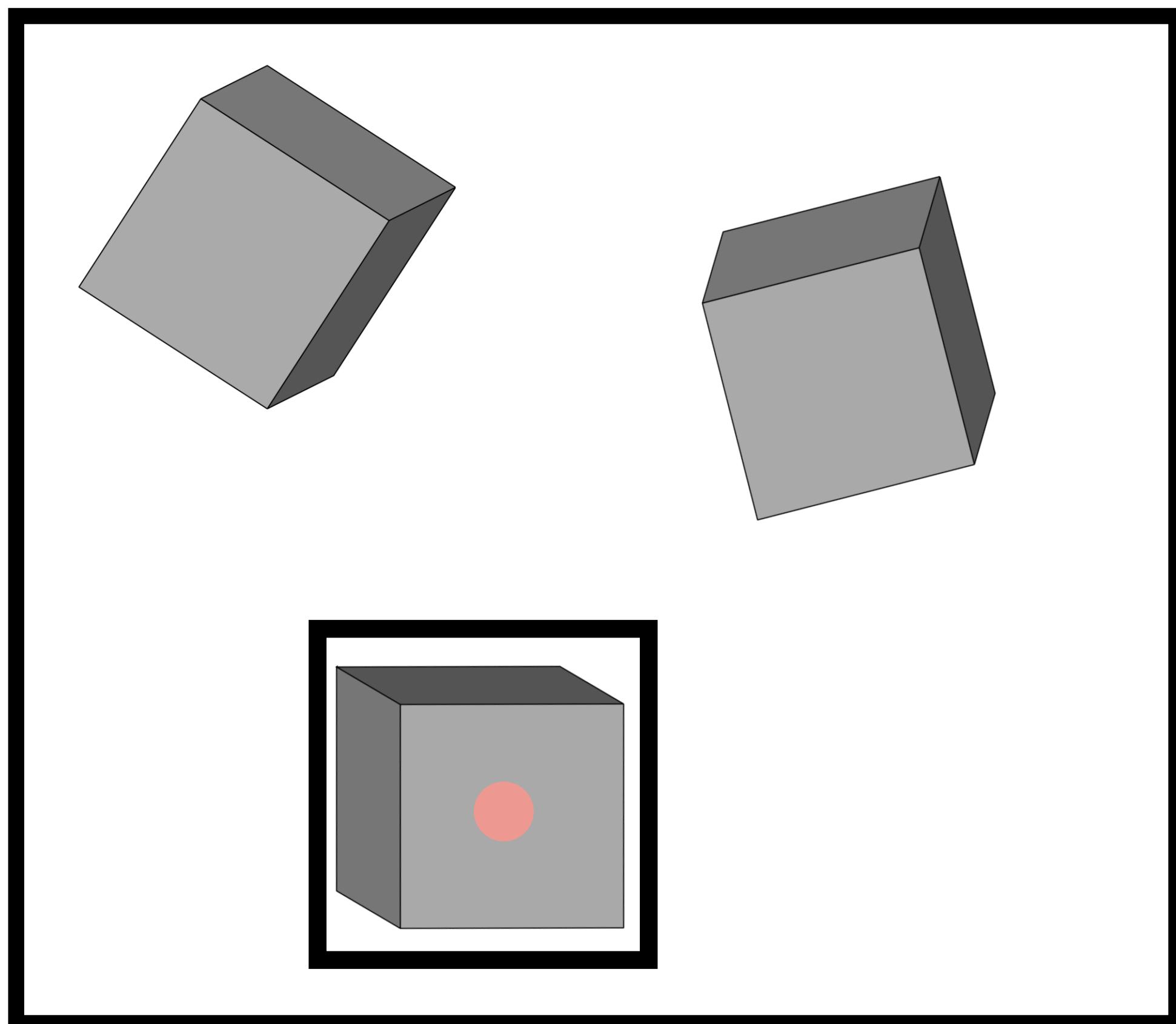


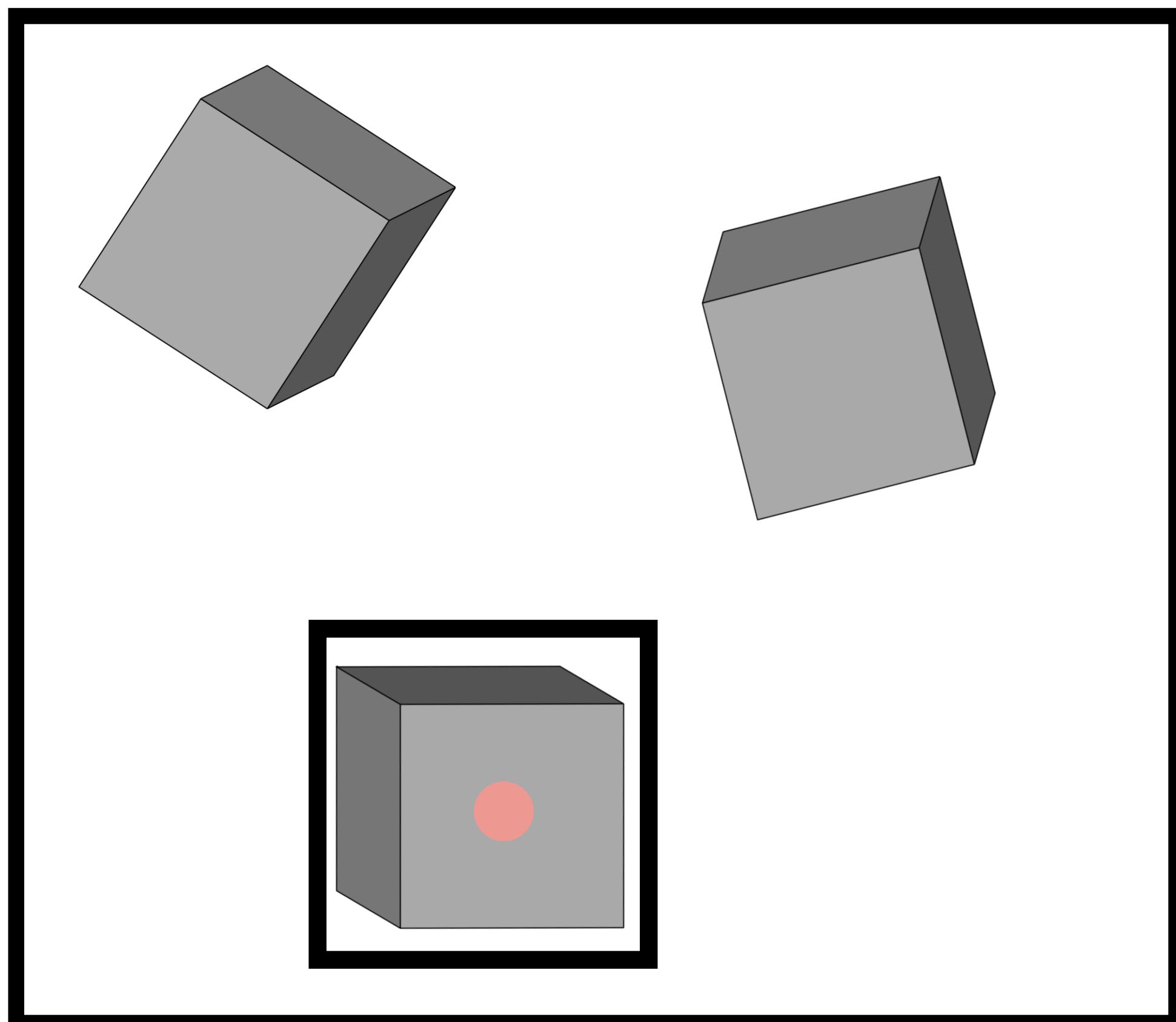
Ray Casting

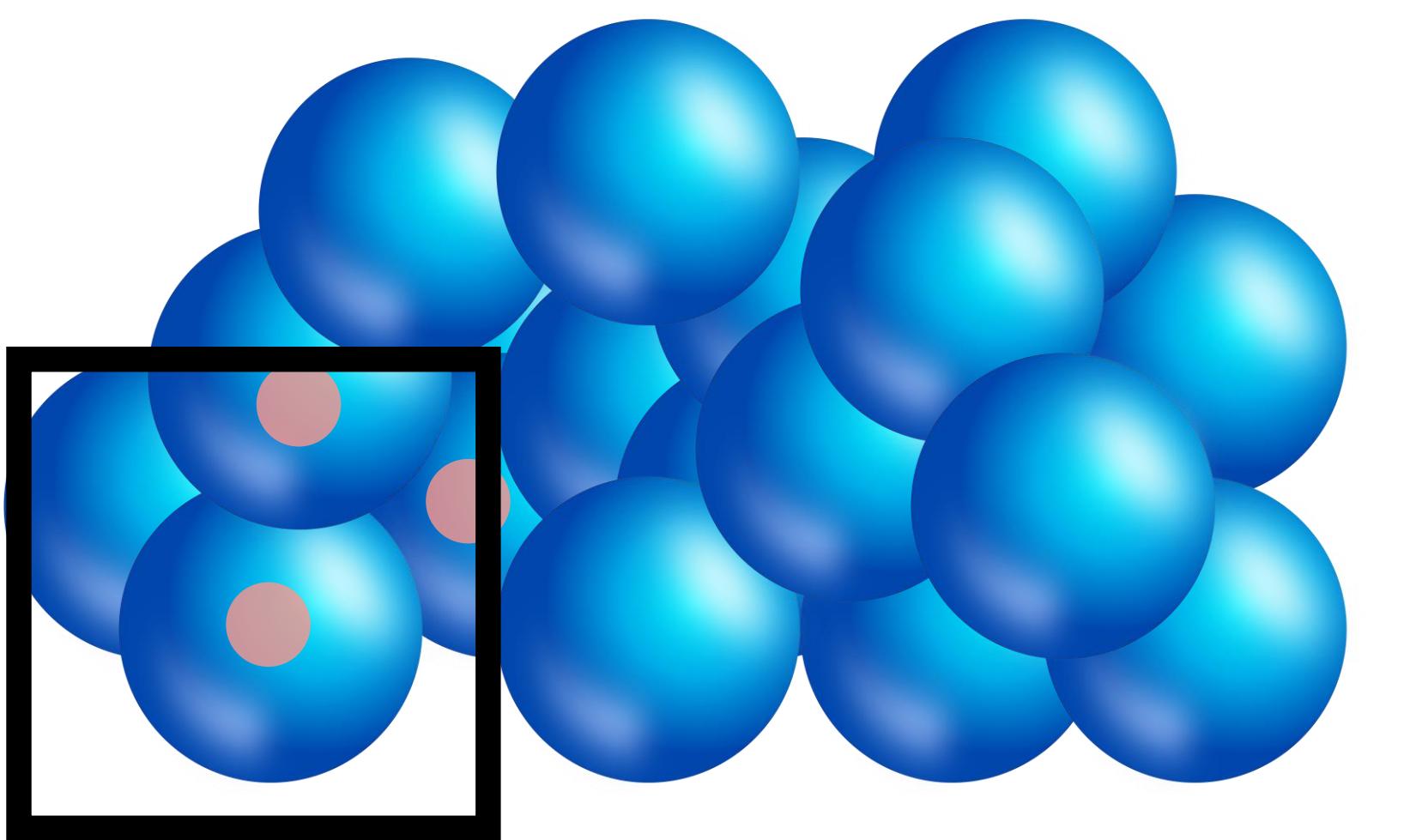


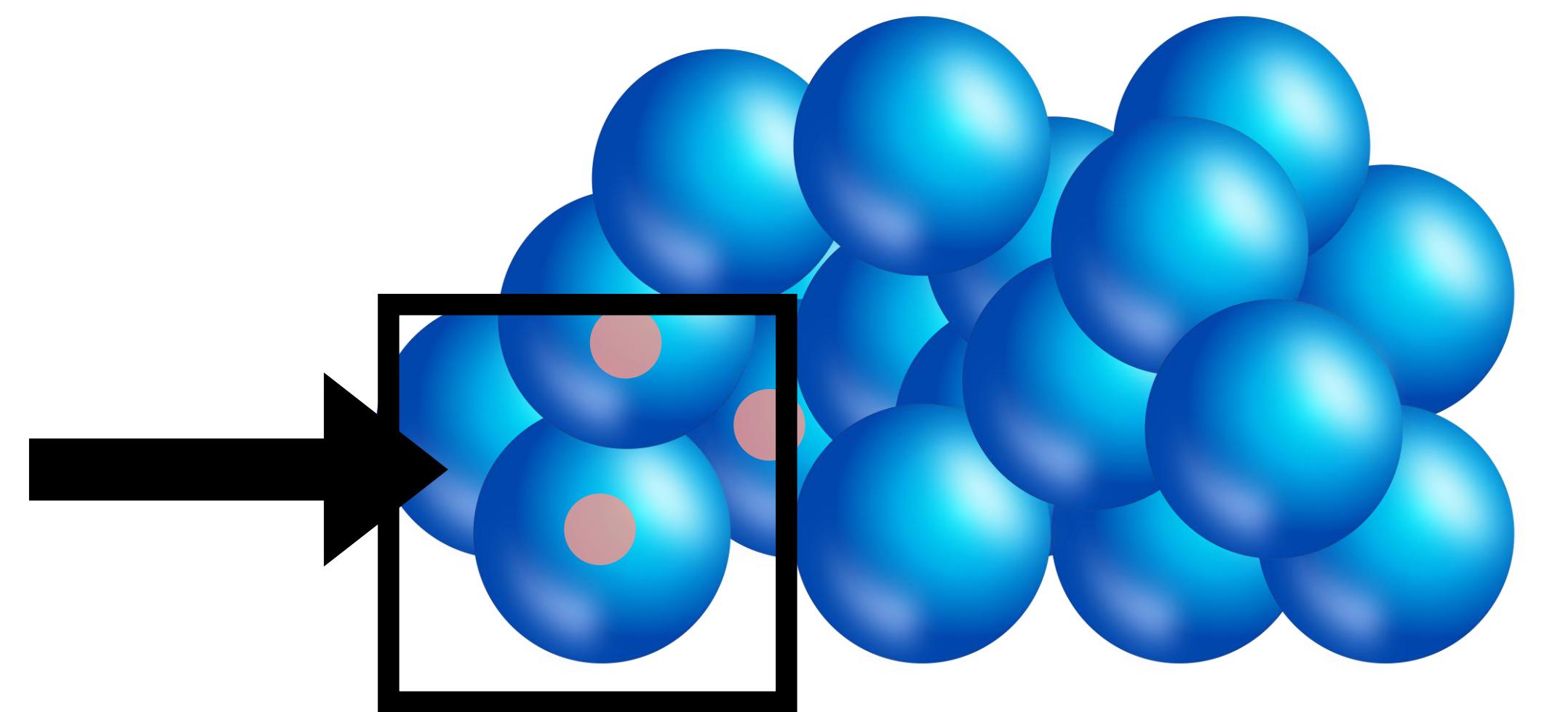
Pre-defined shapes

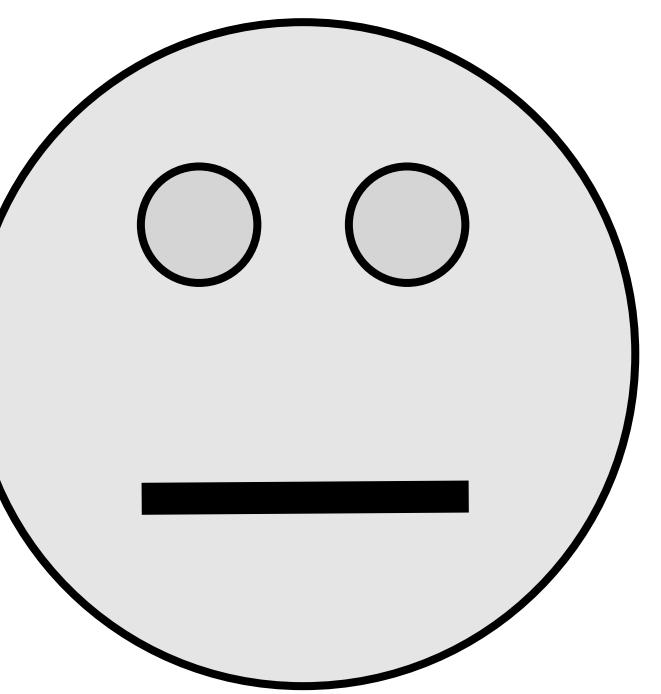
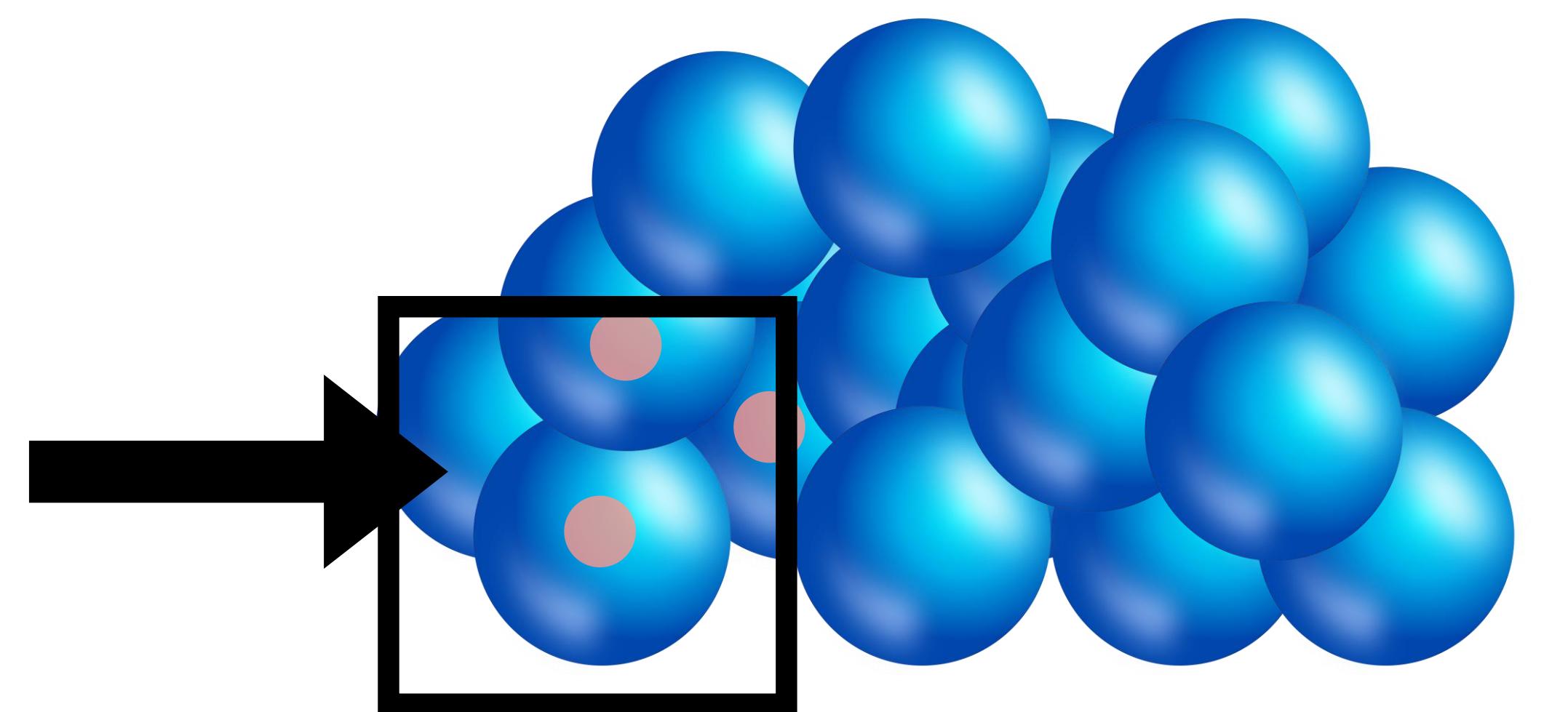


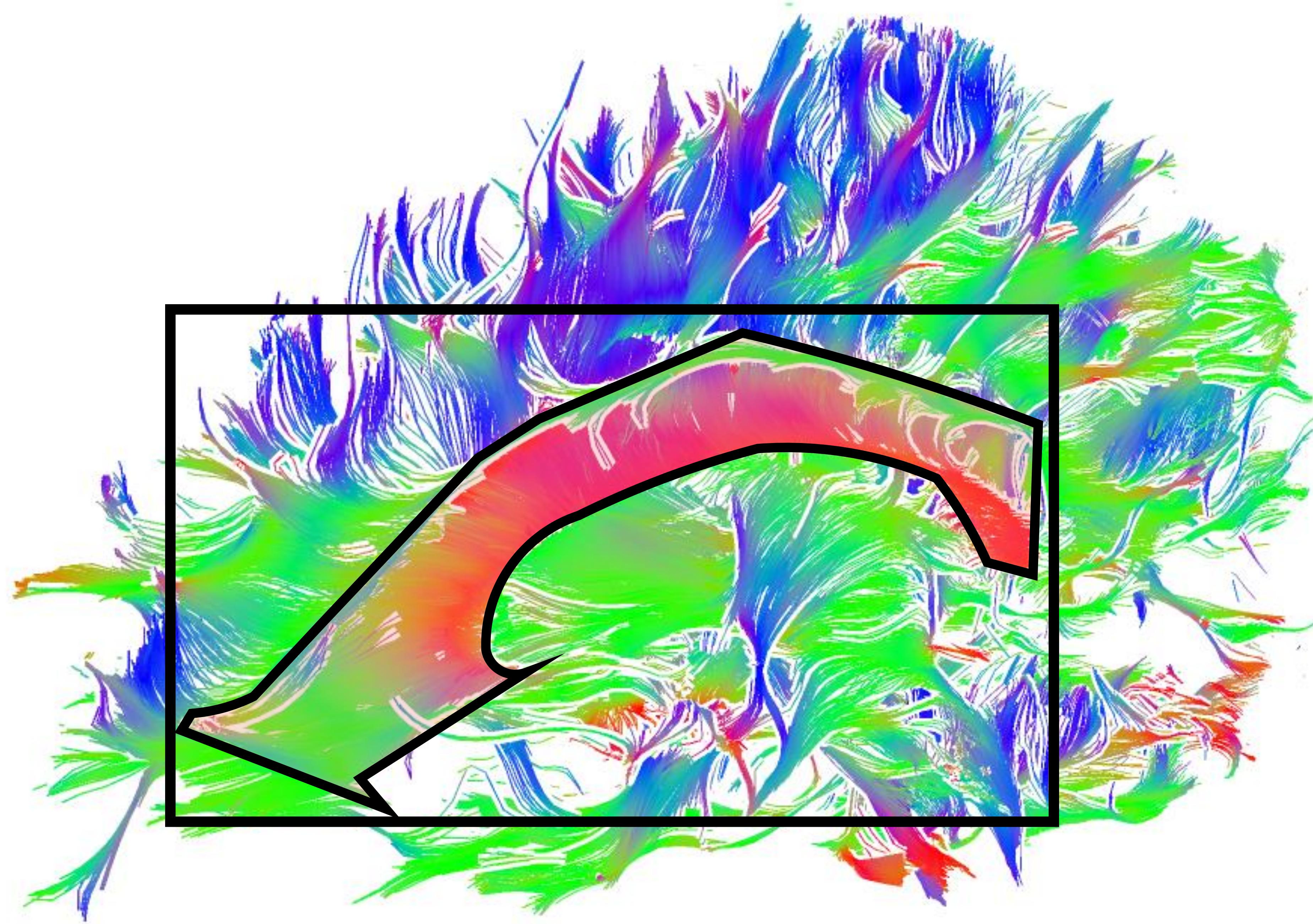


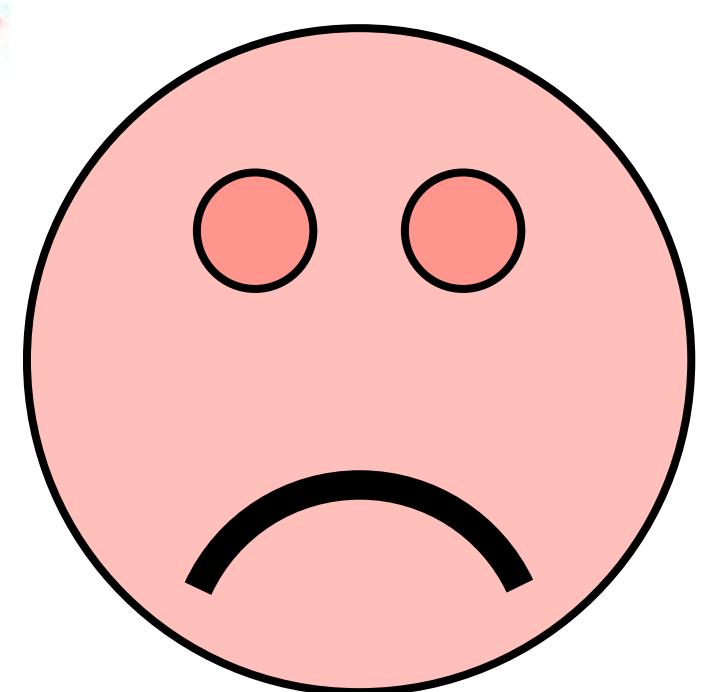
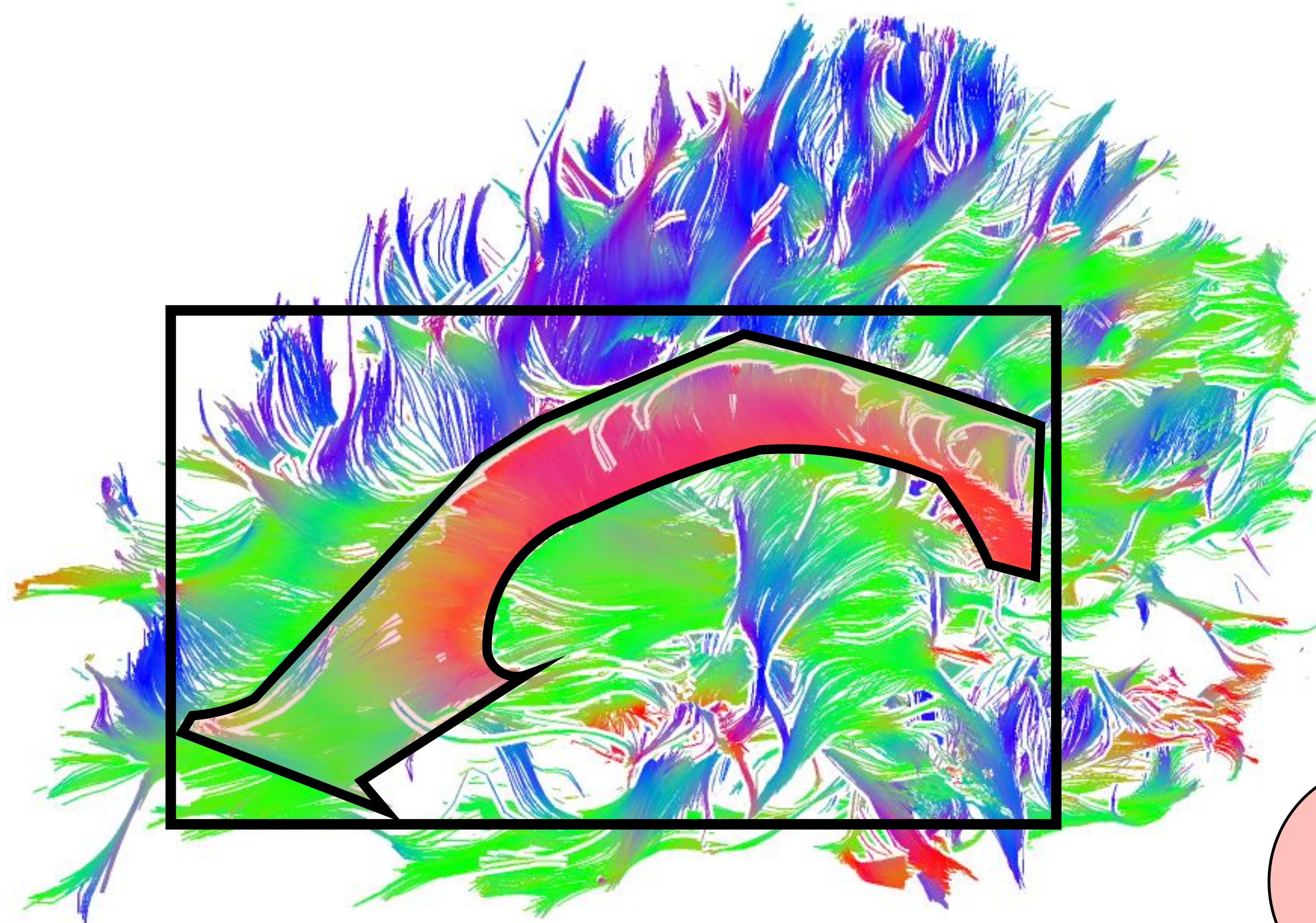




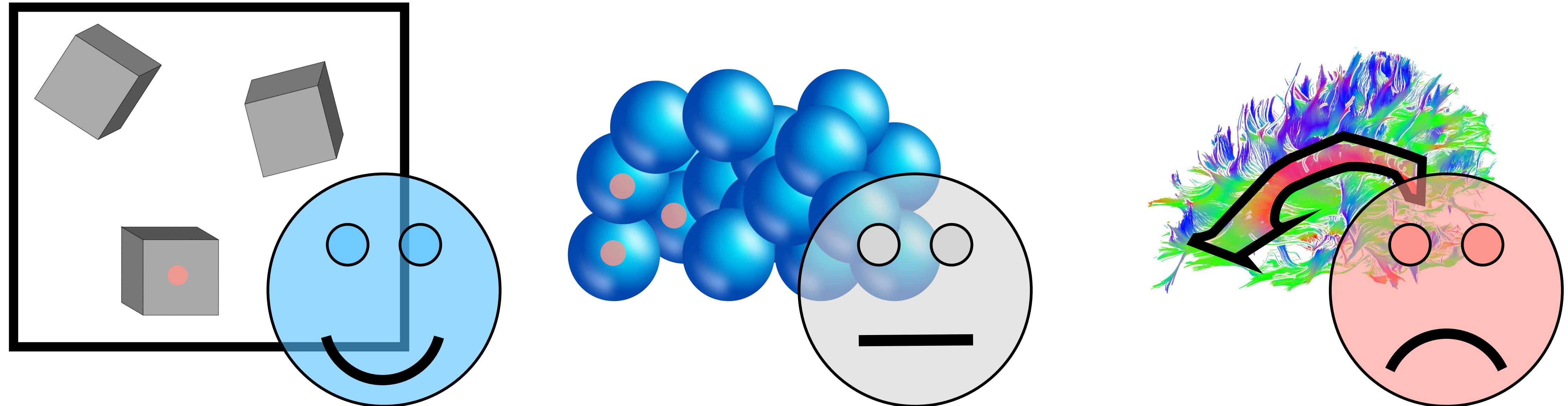




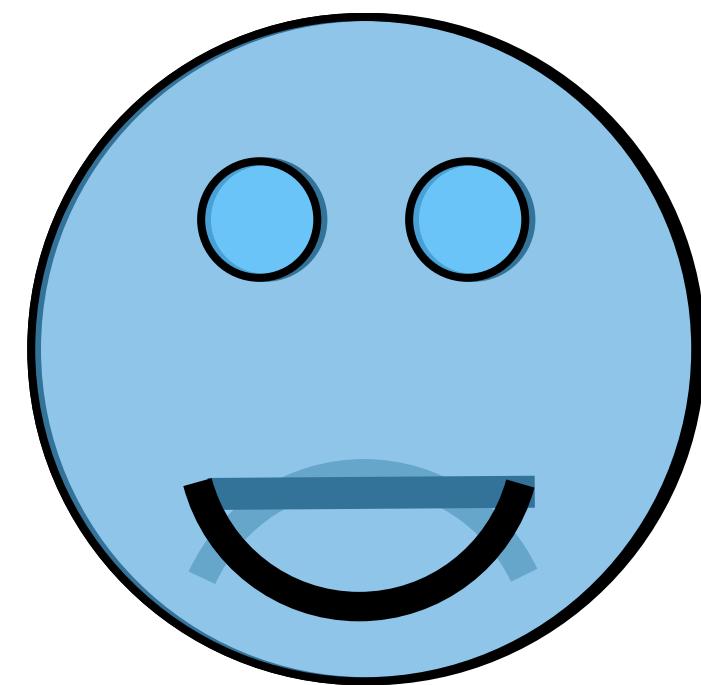




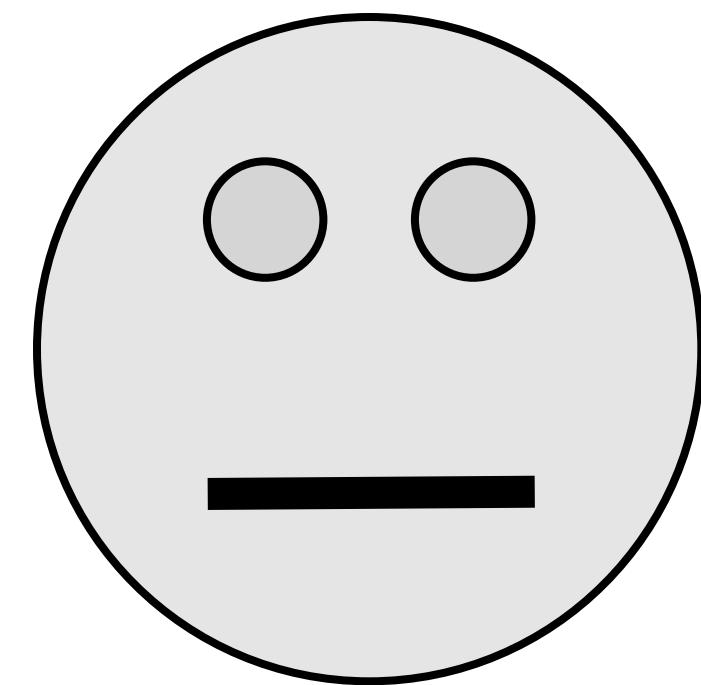
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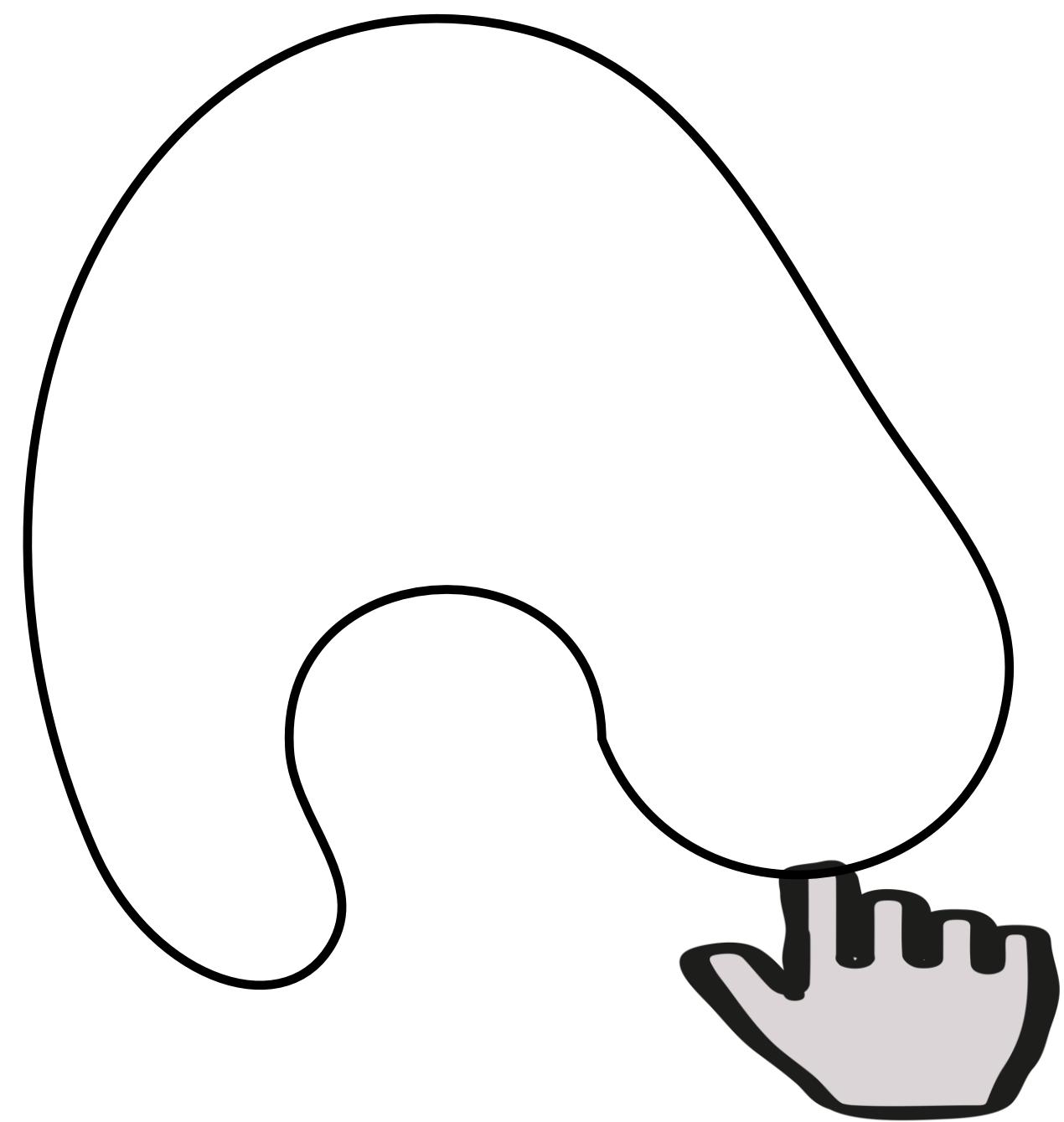
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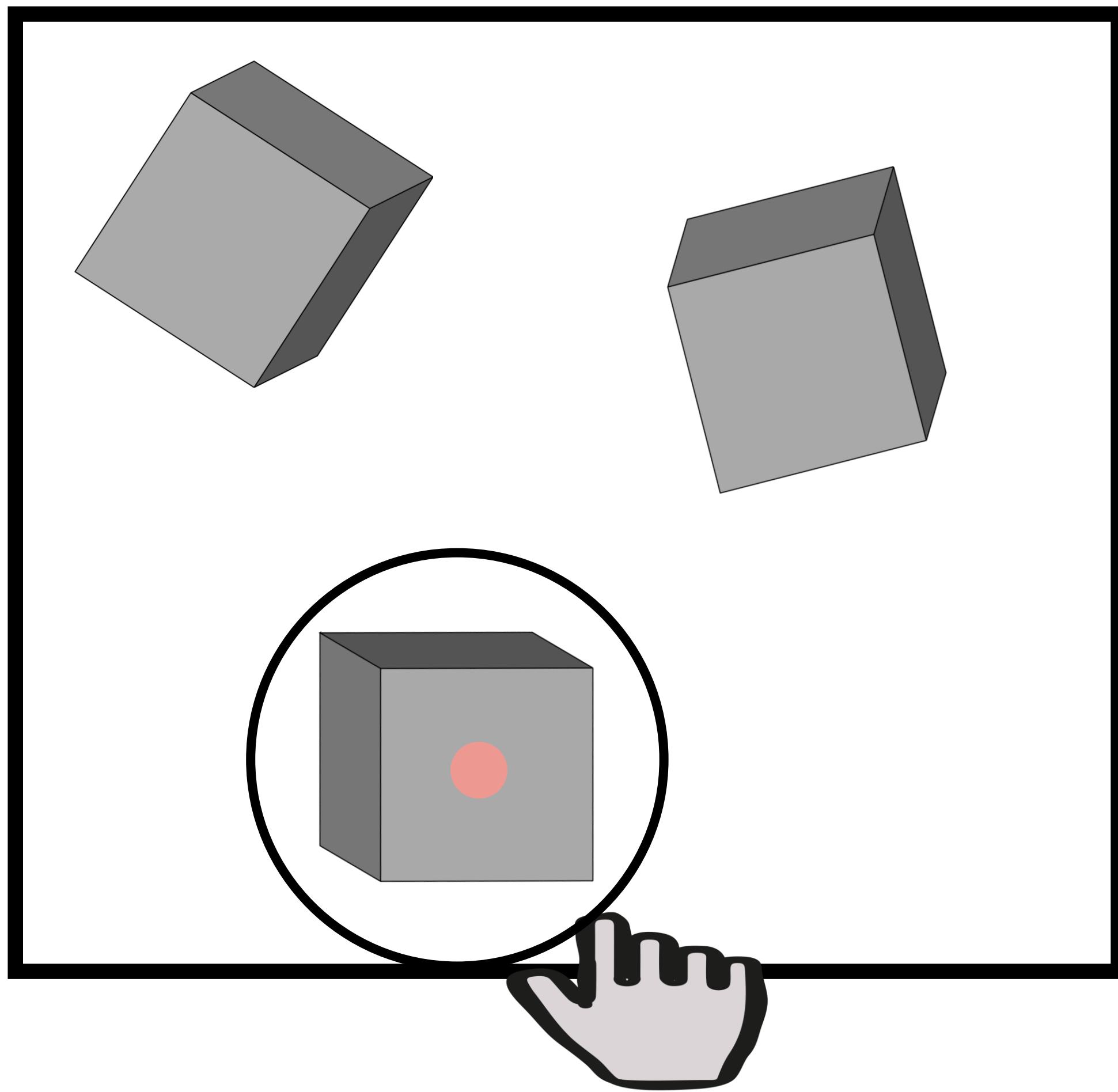


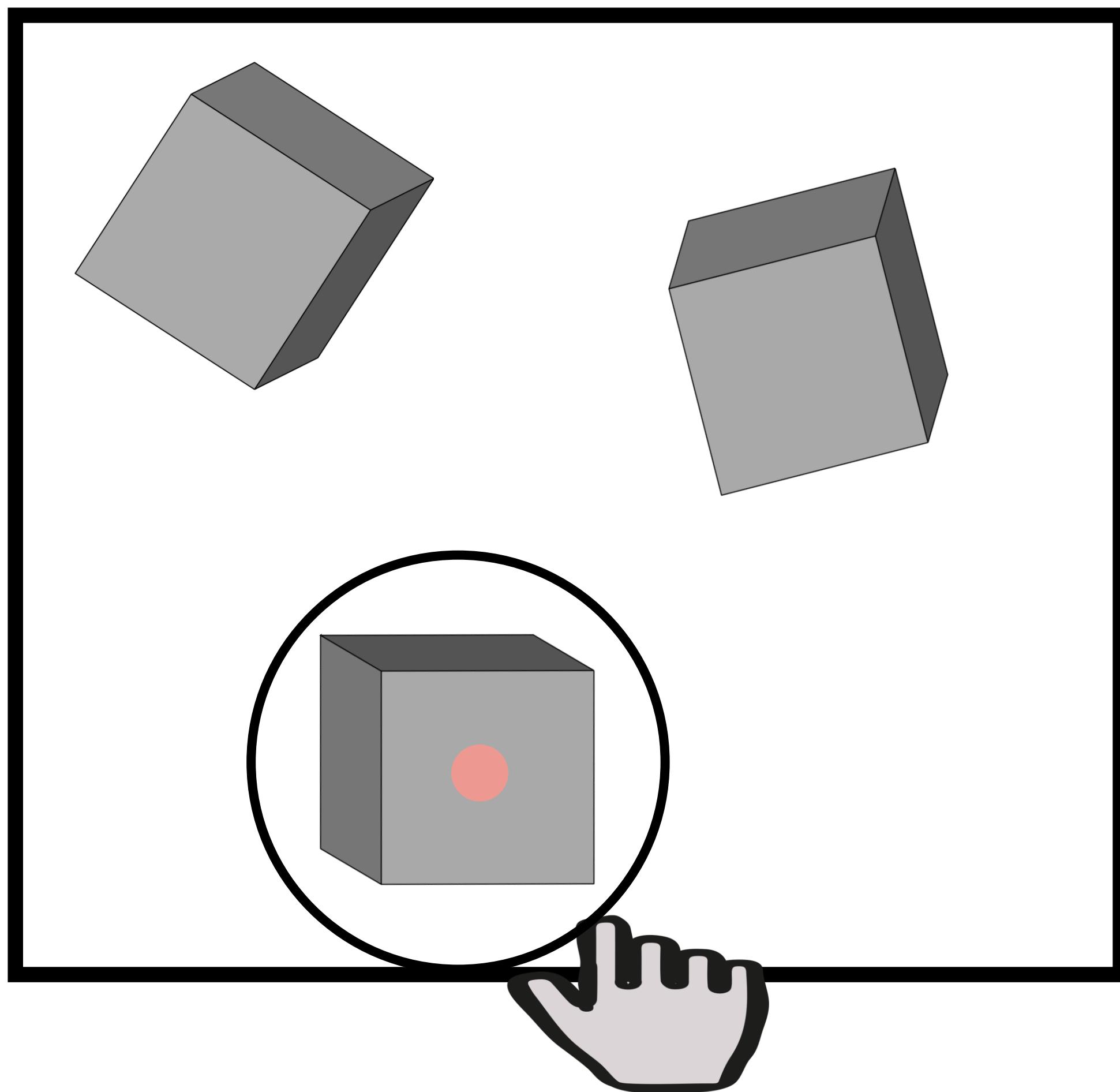
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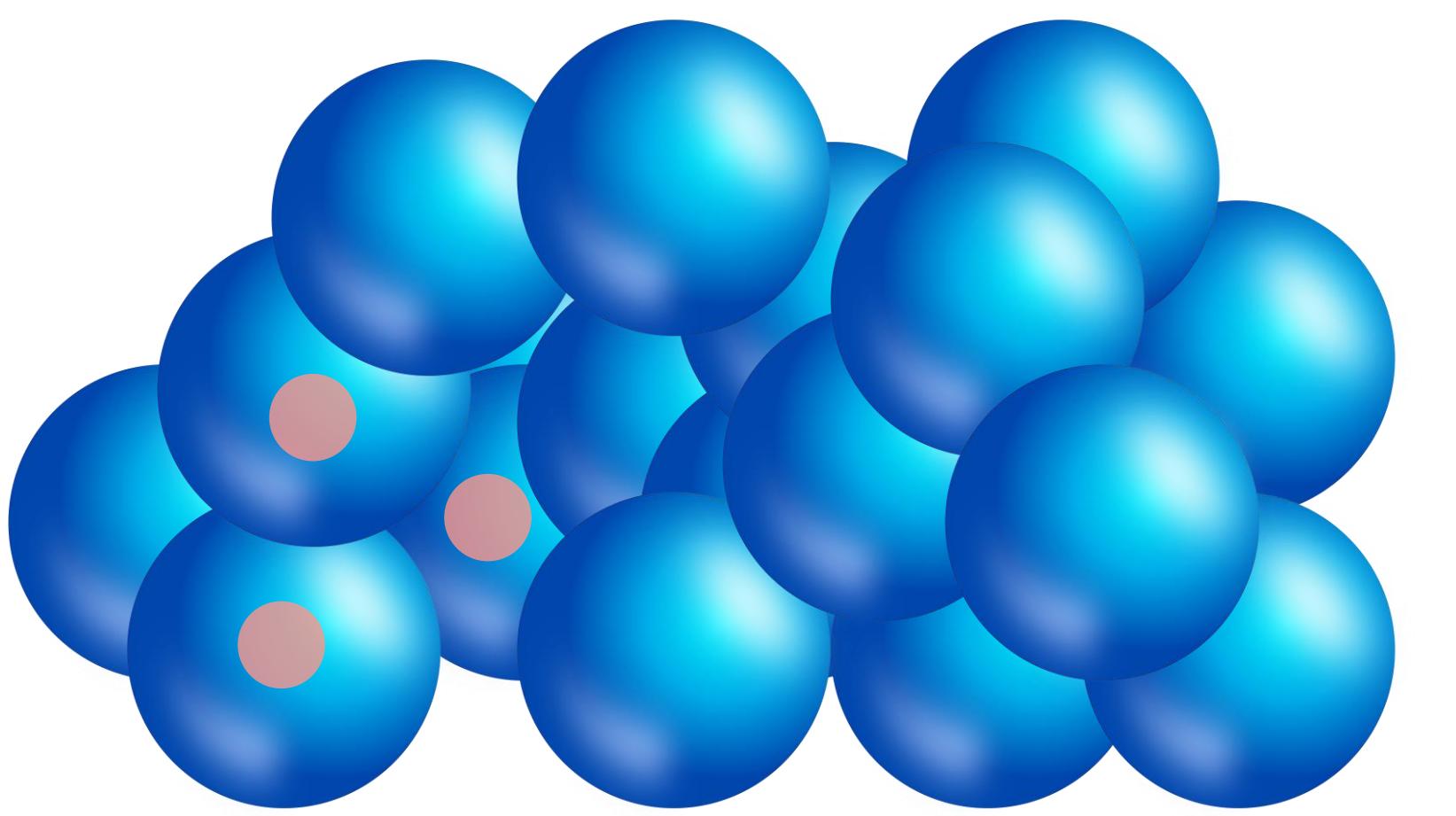


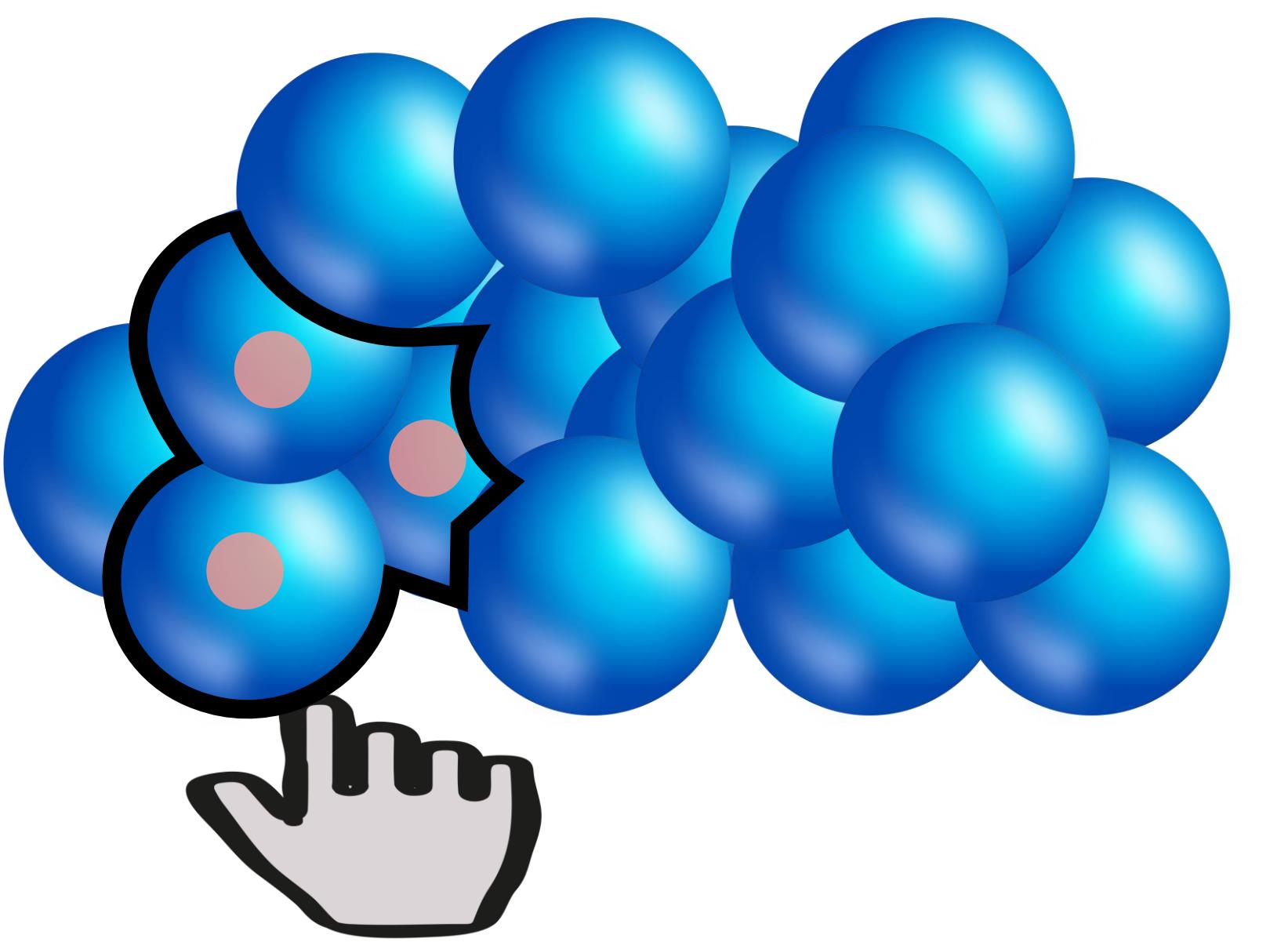
Lasso

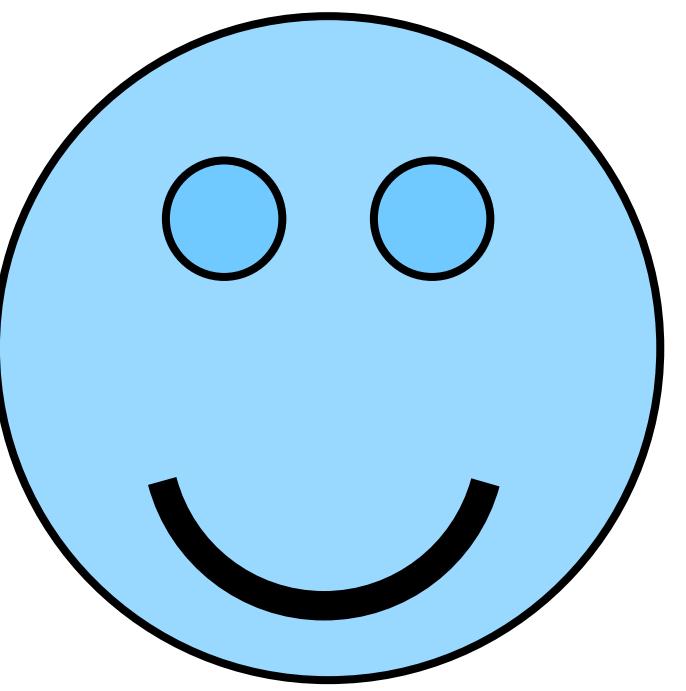
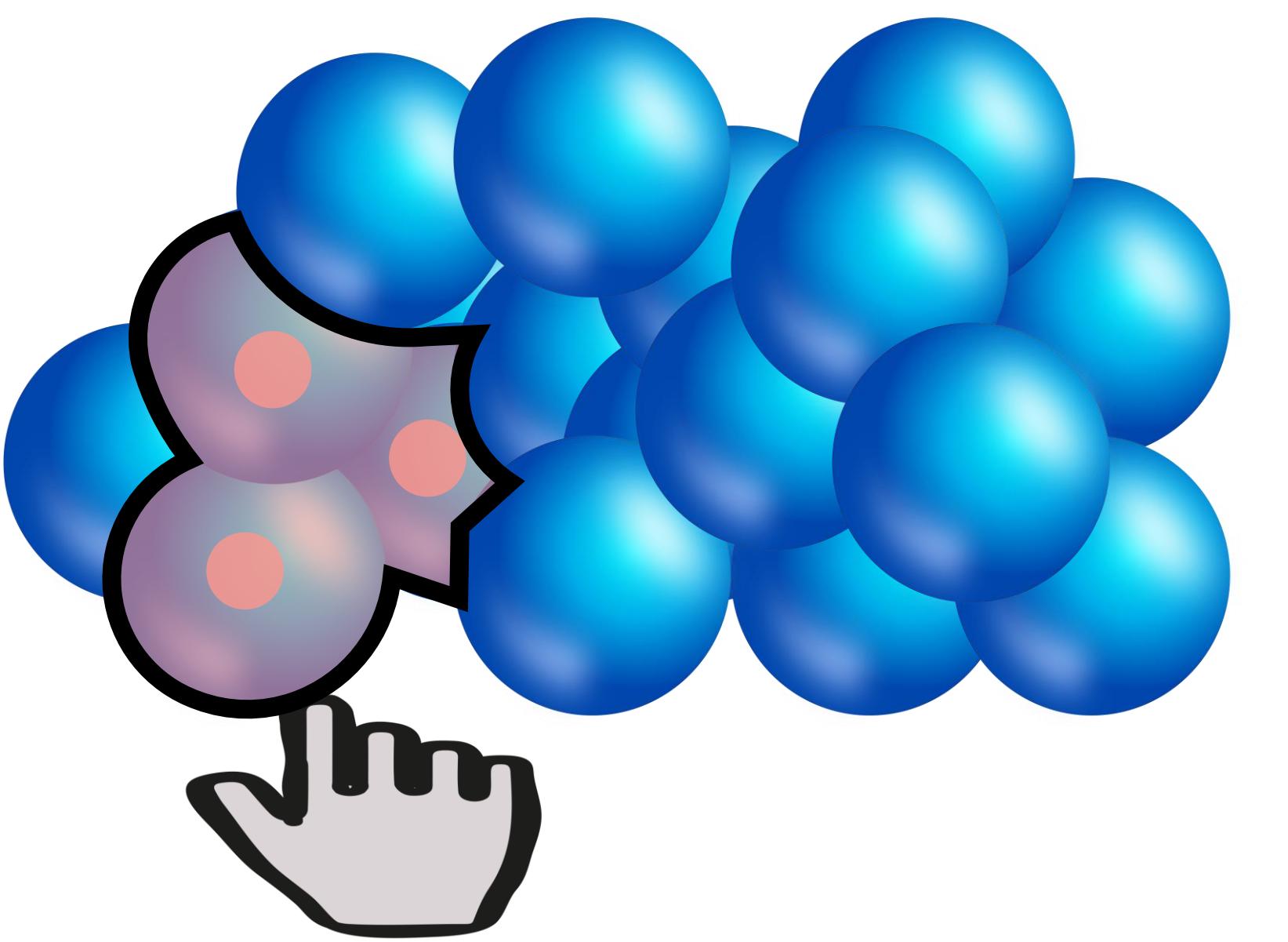


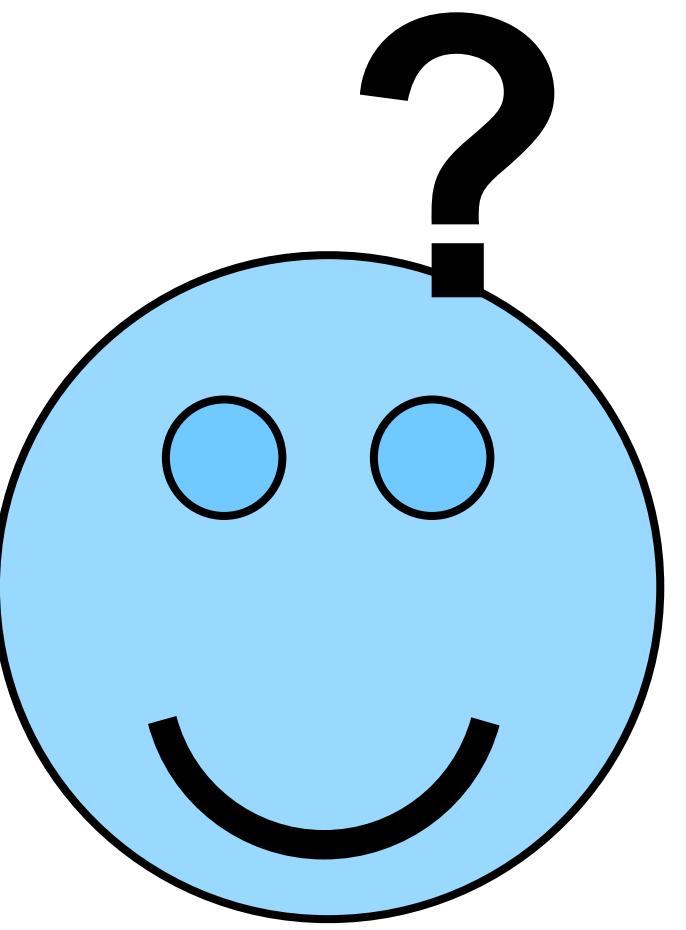
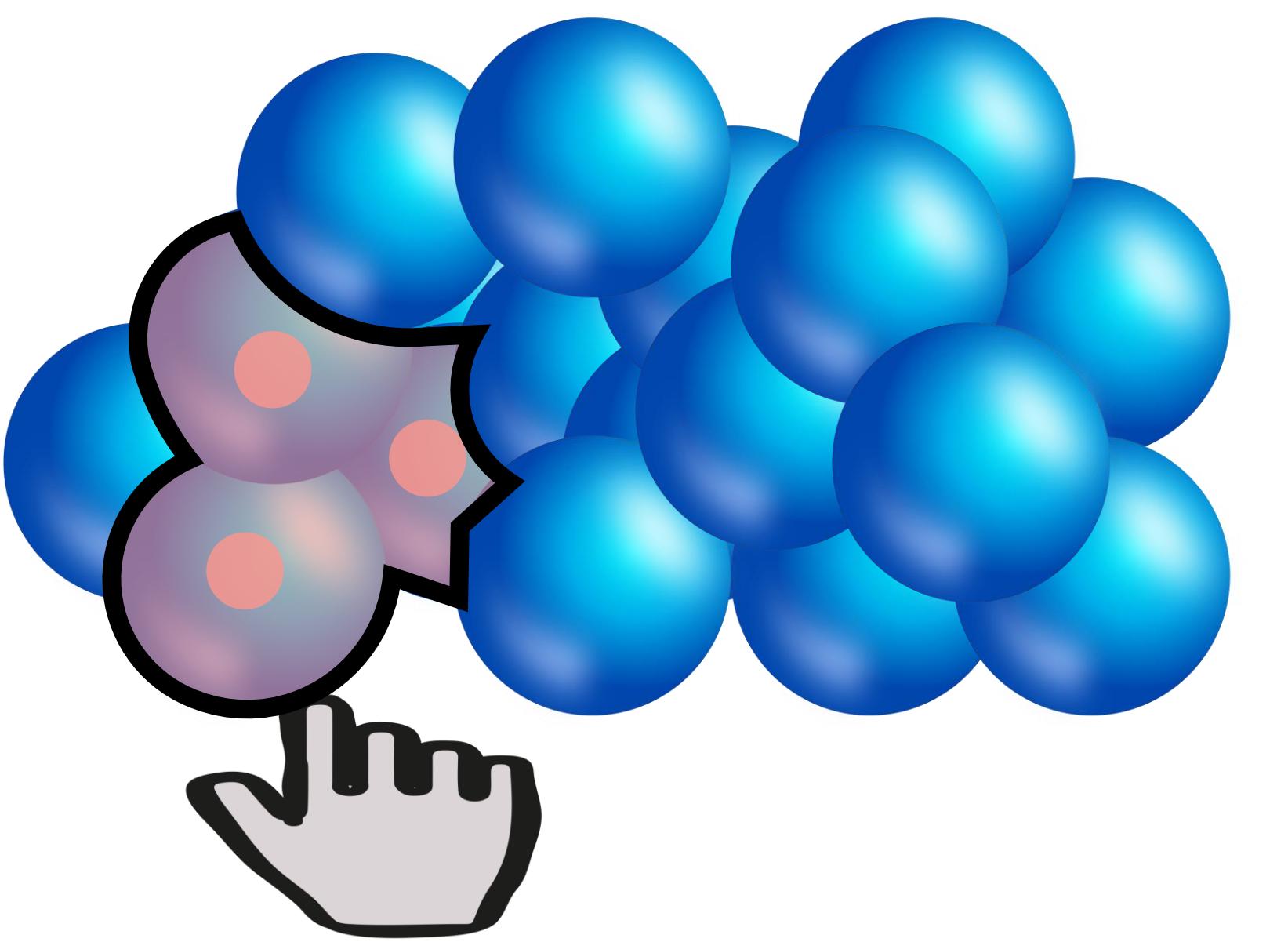


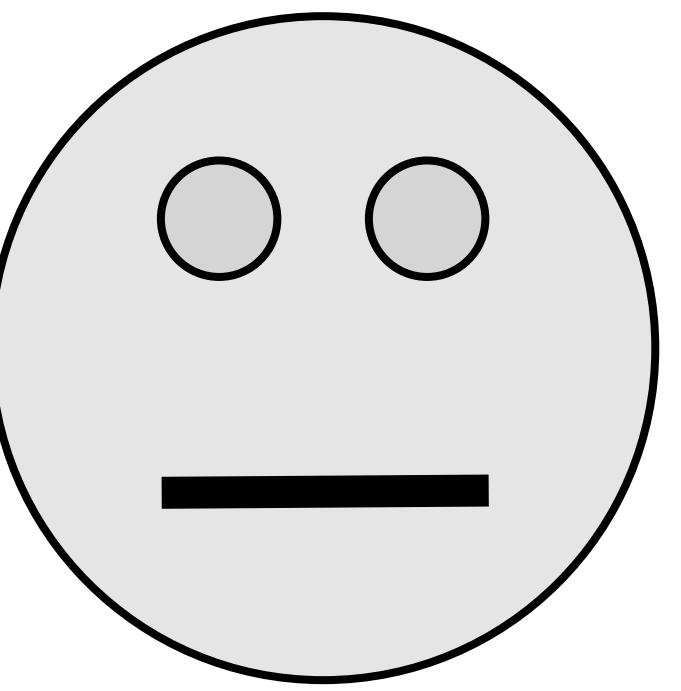
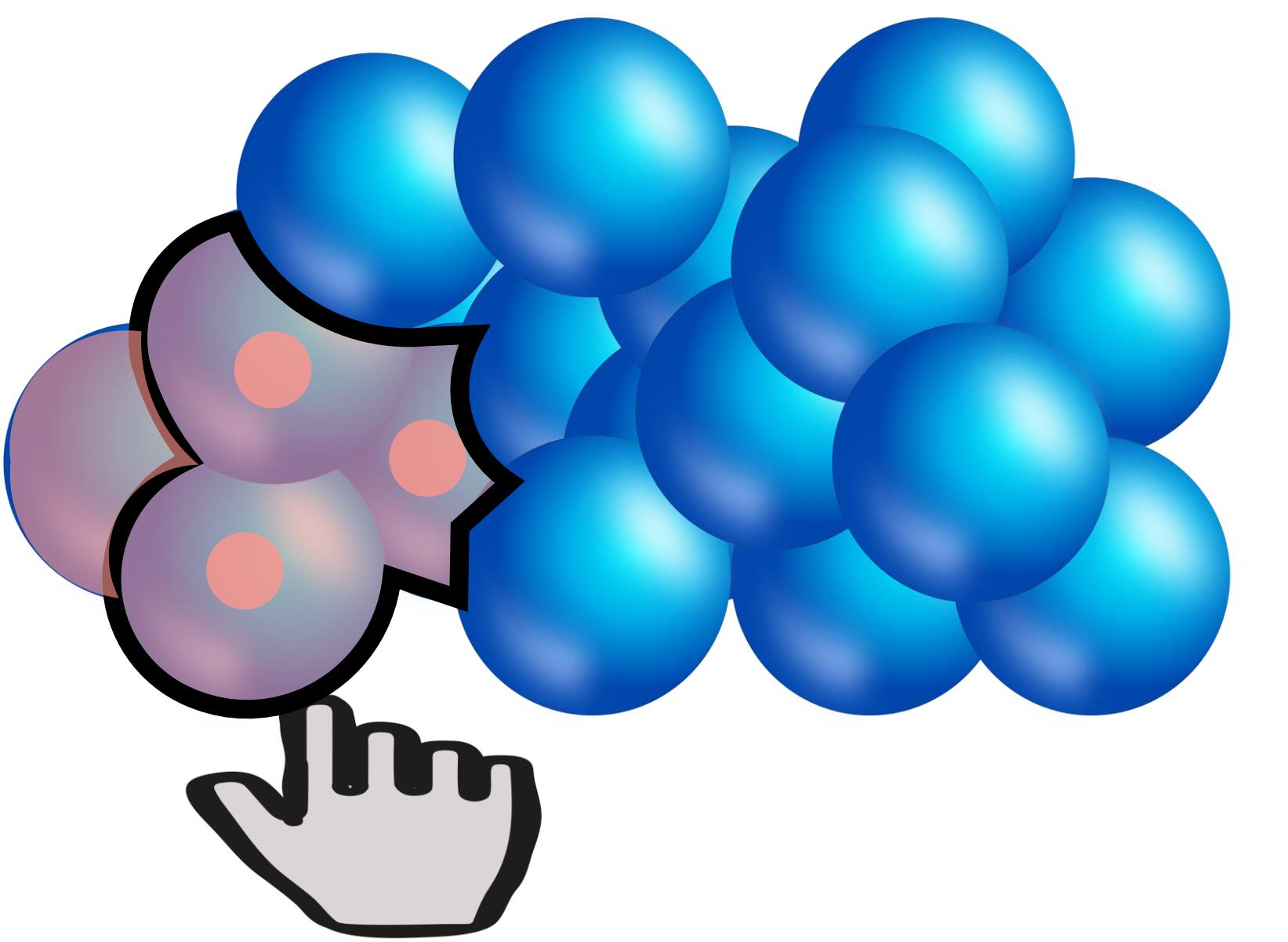


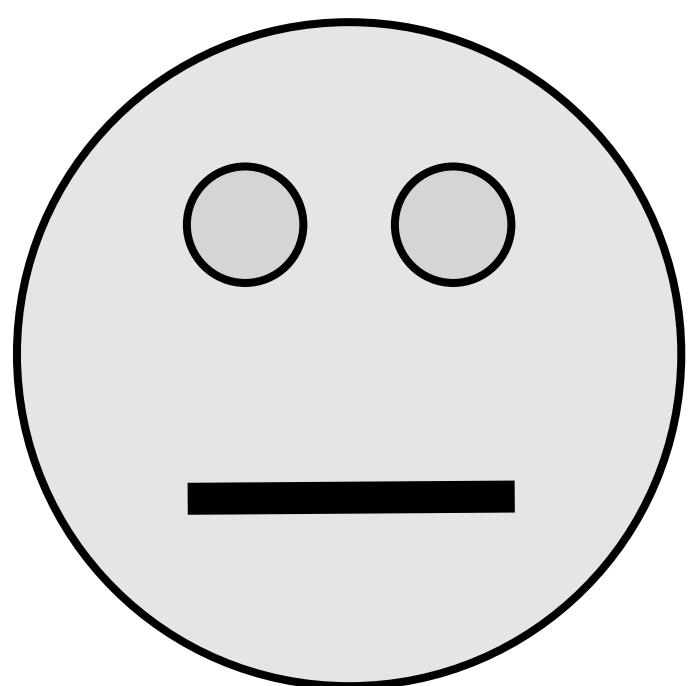
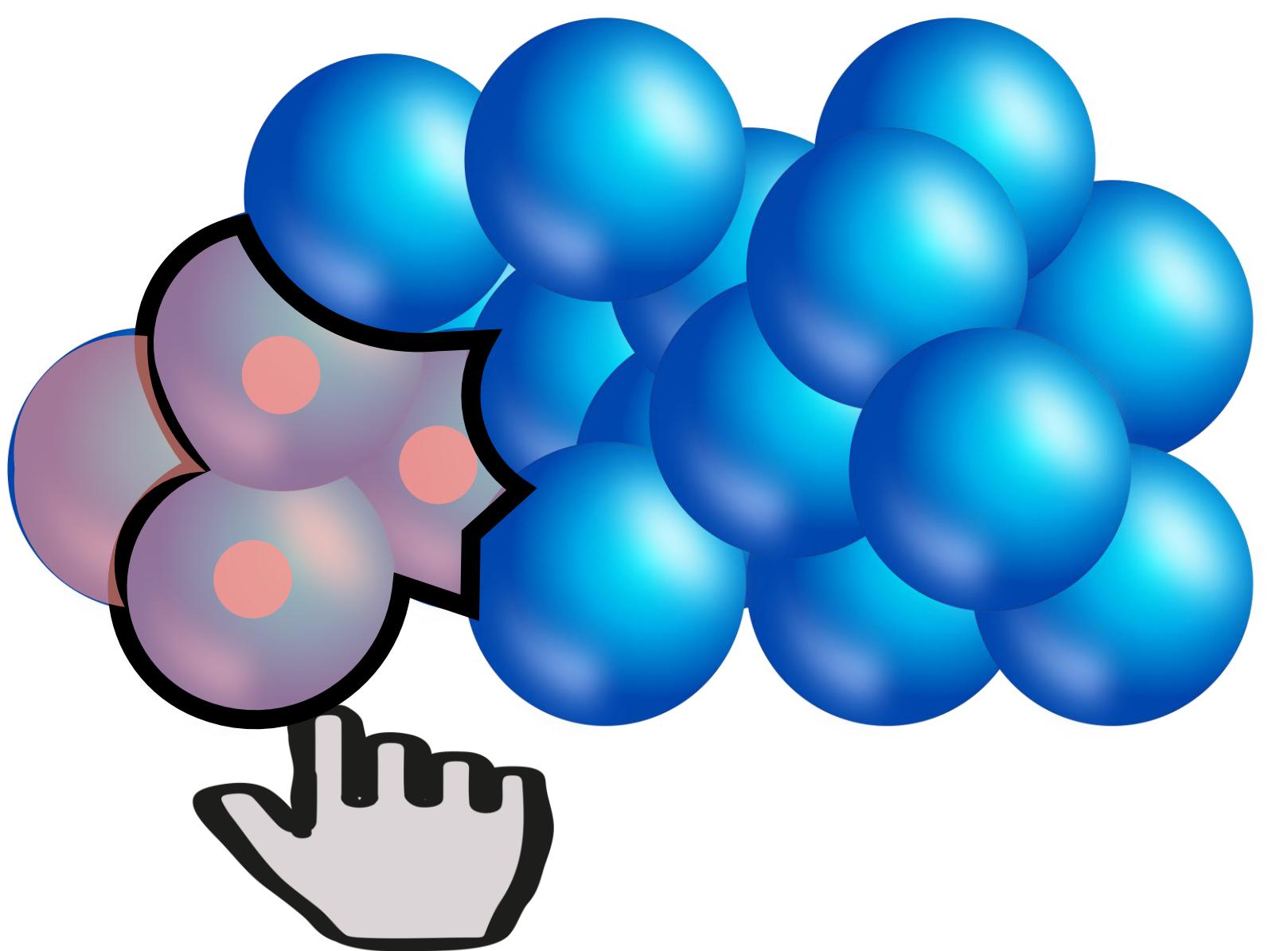


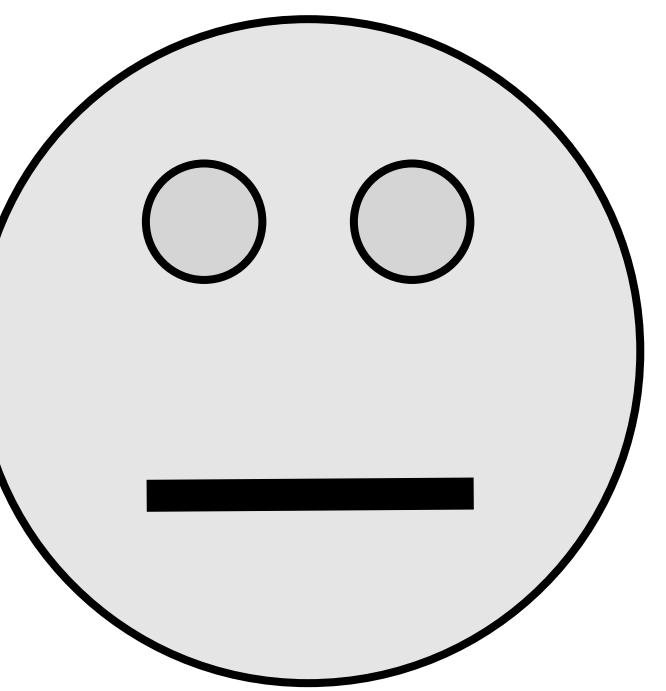
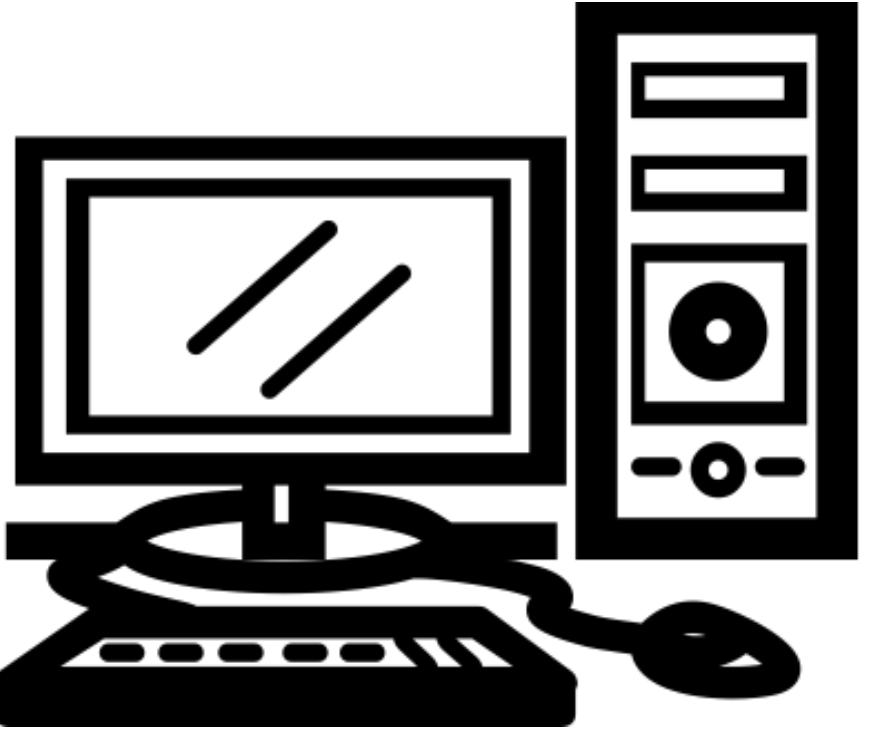
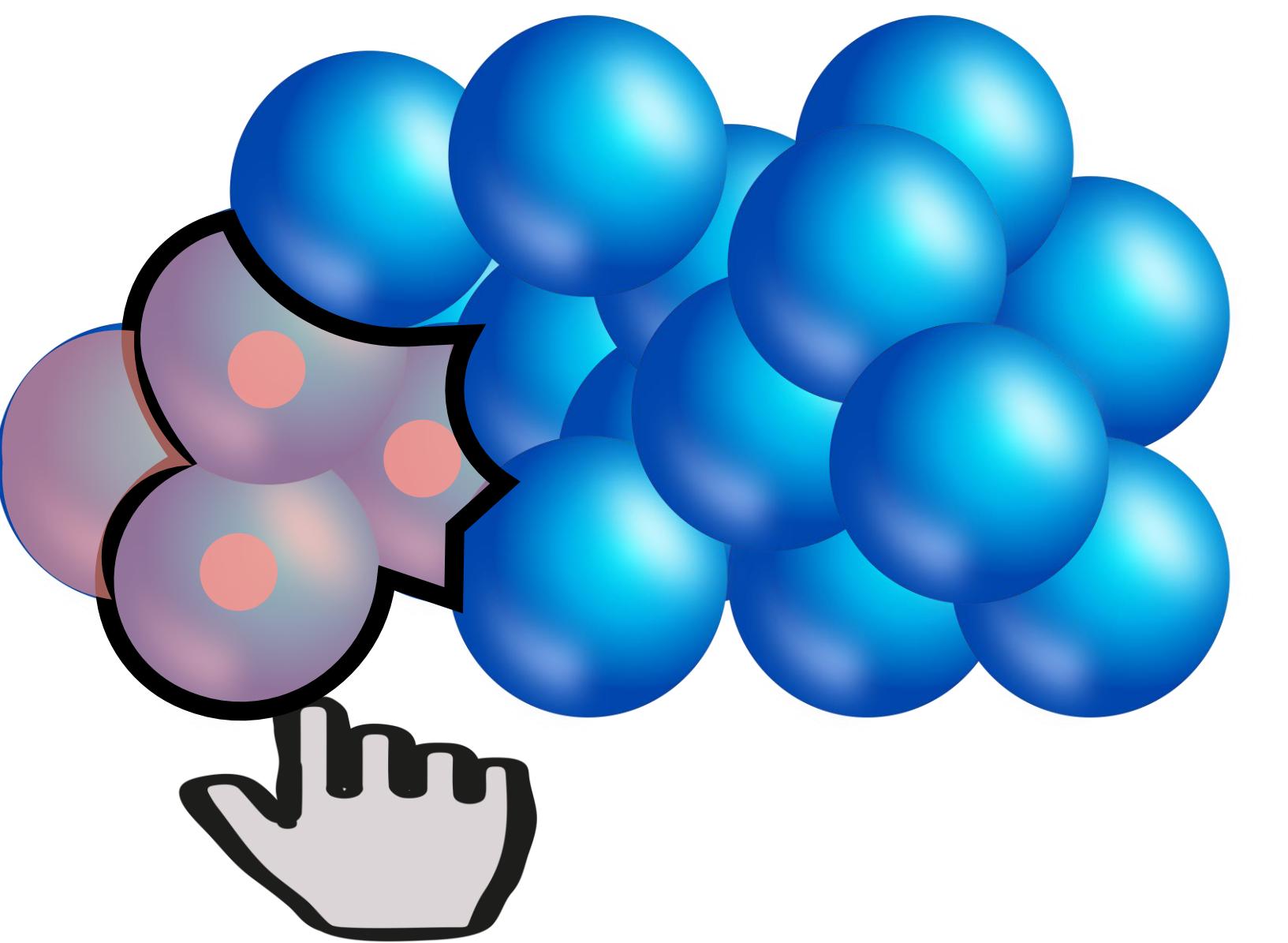
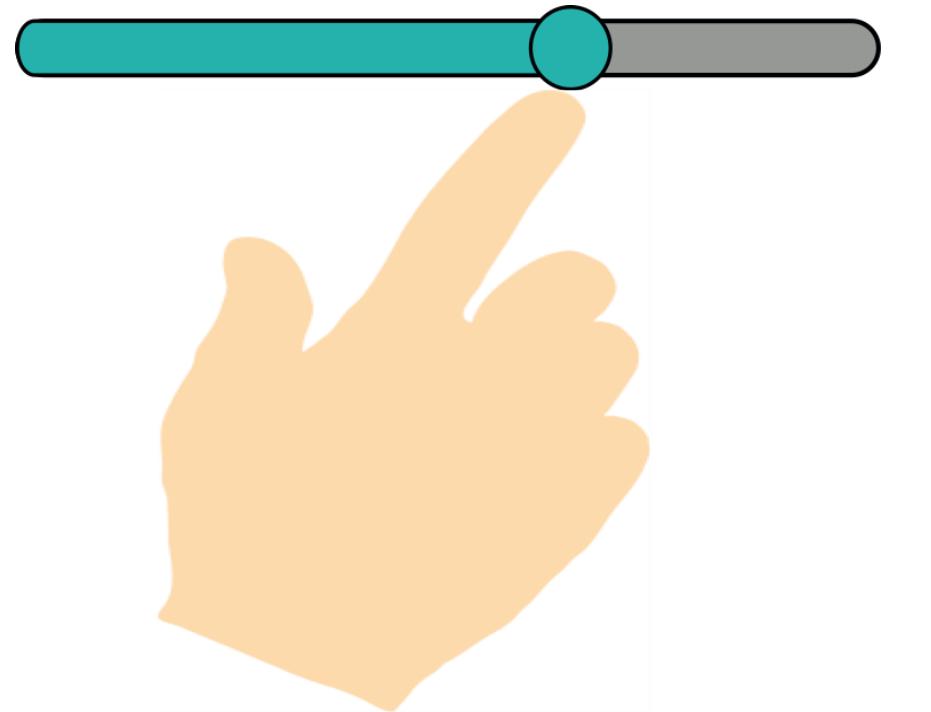


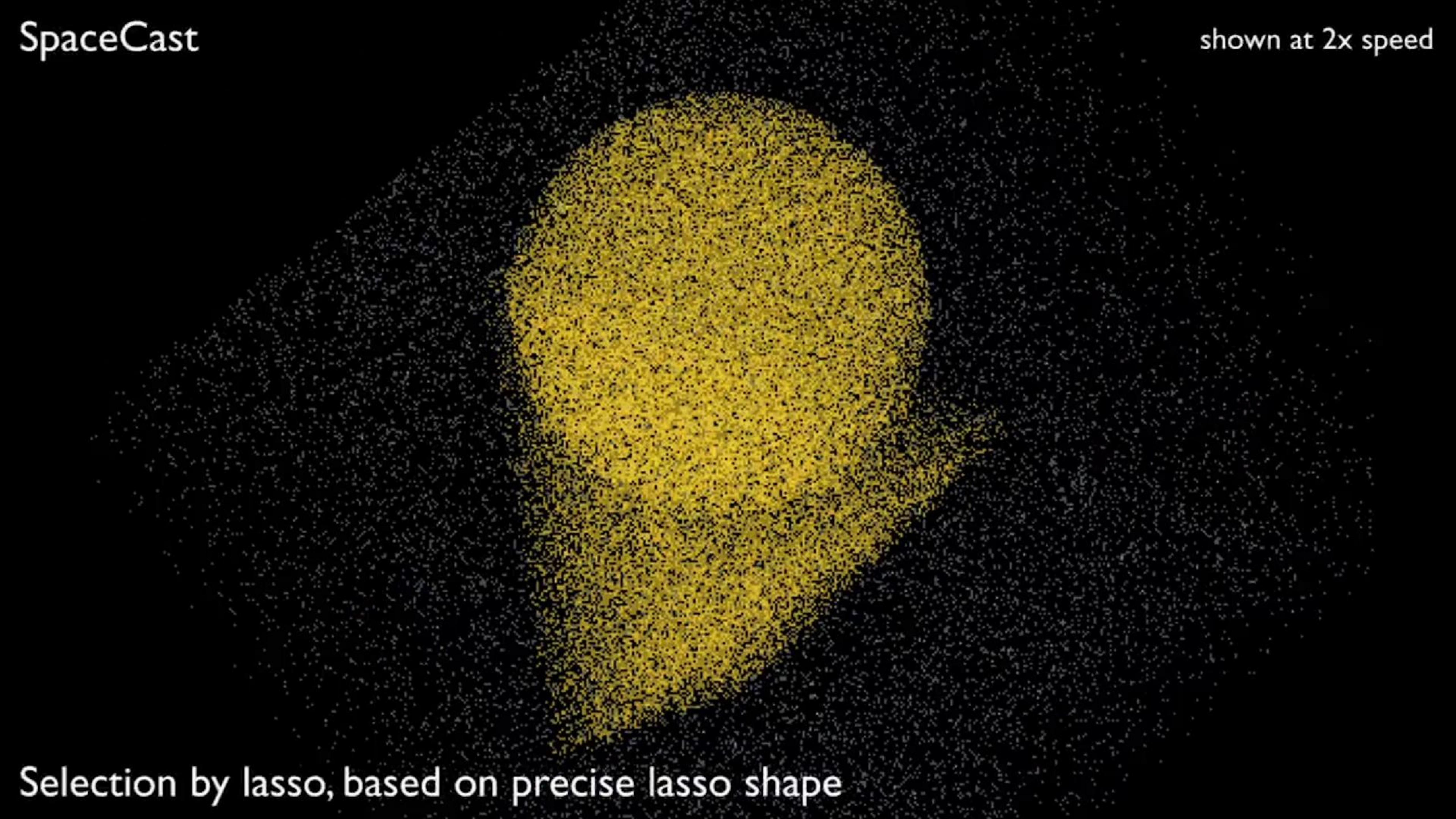




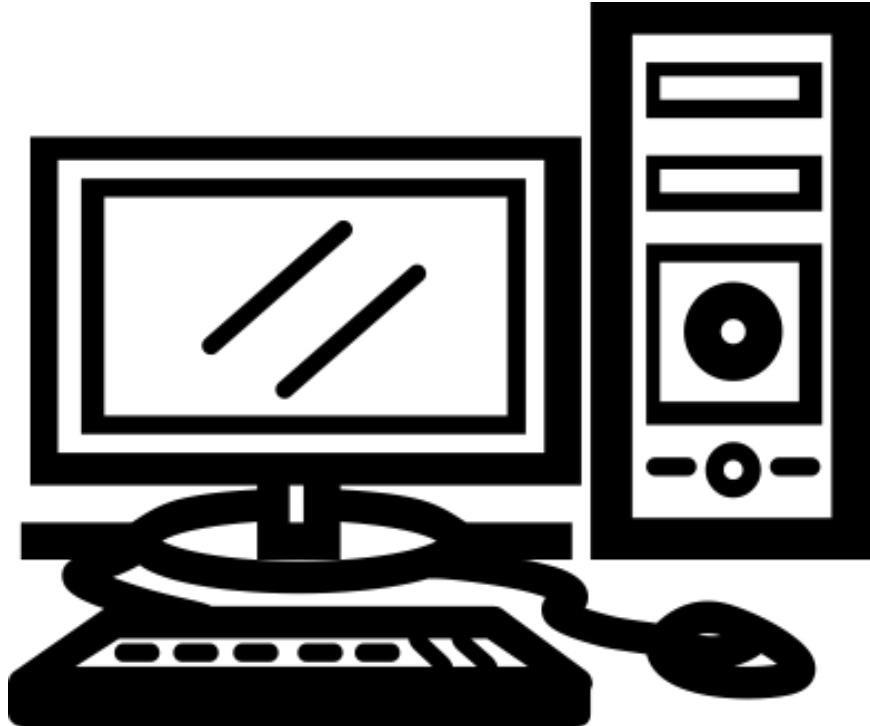
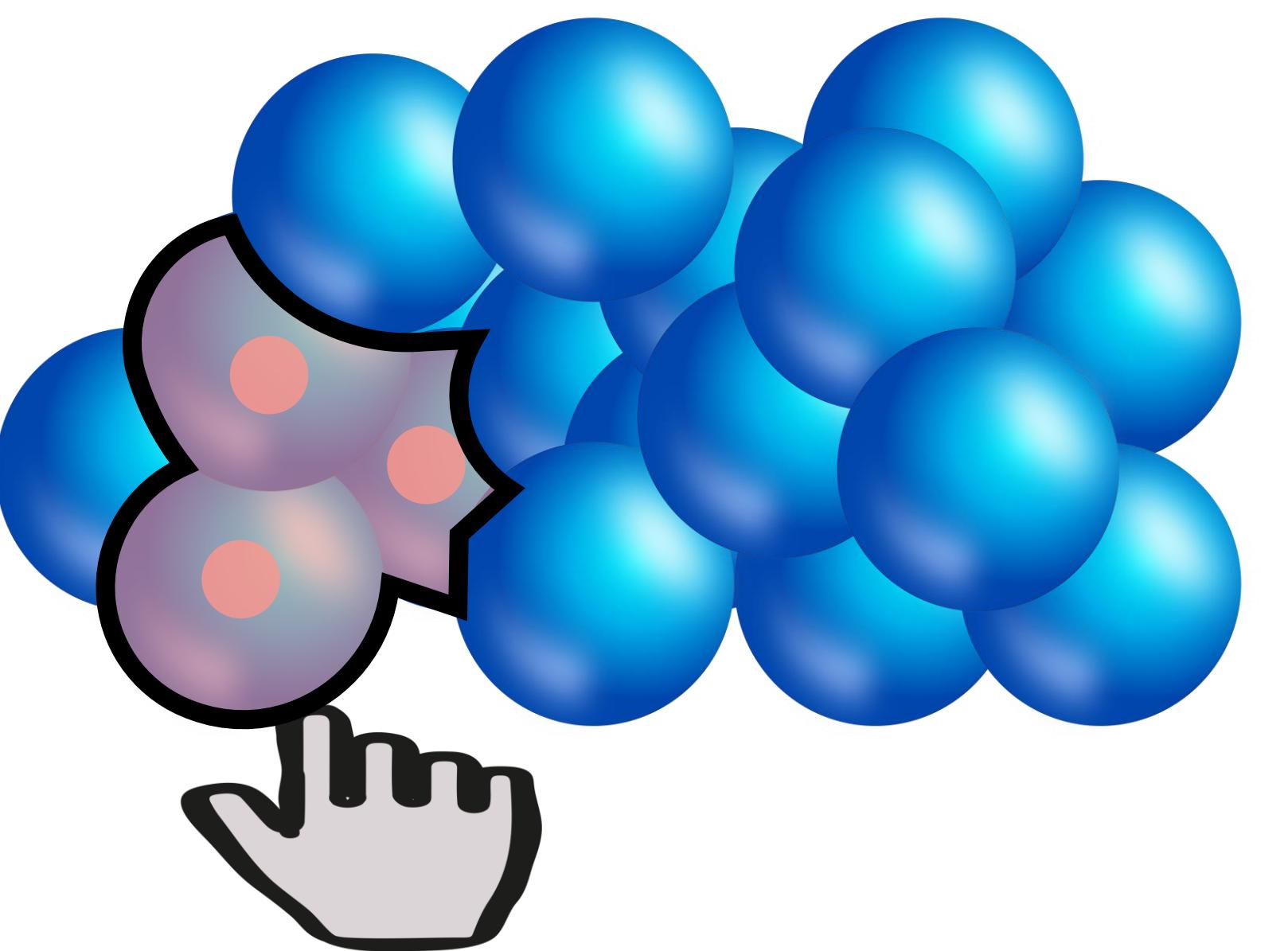
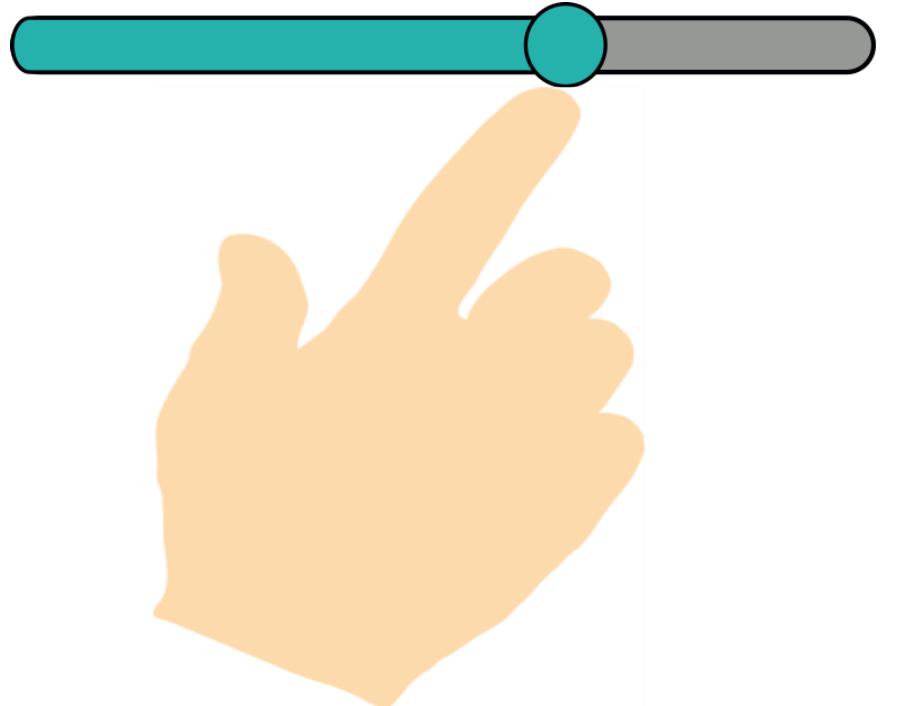






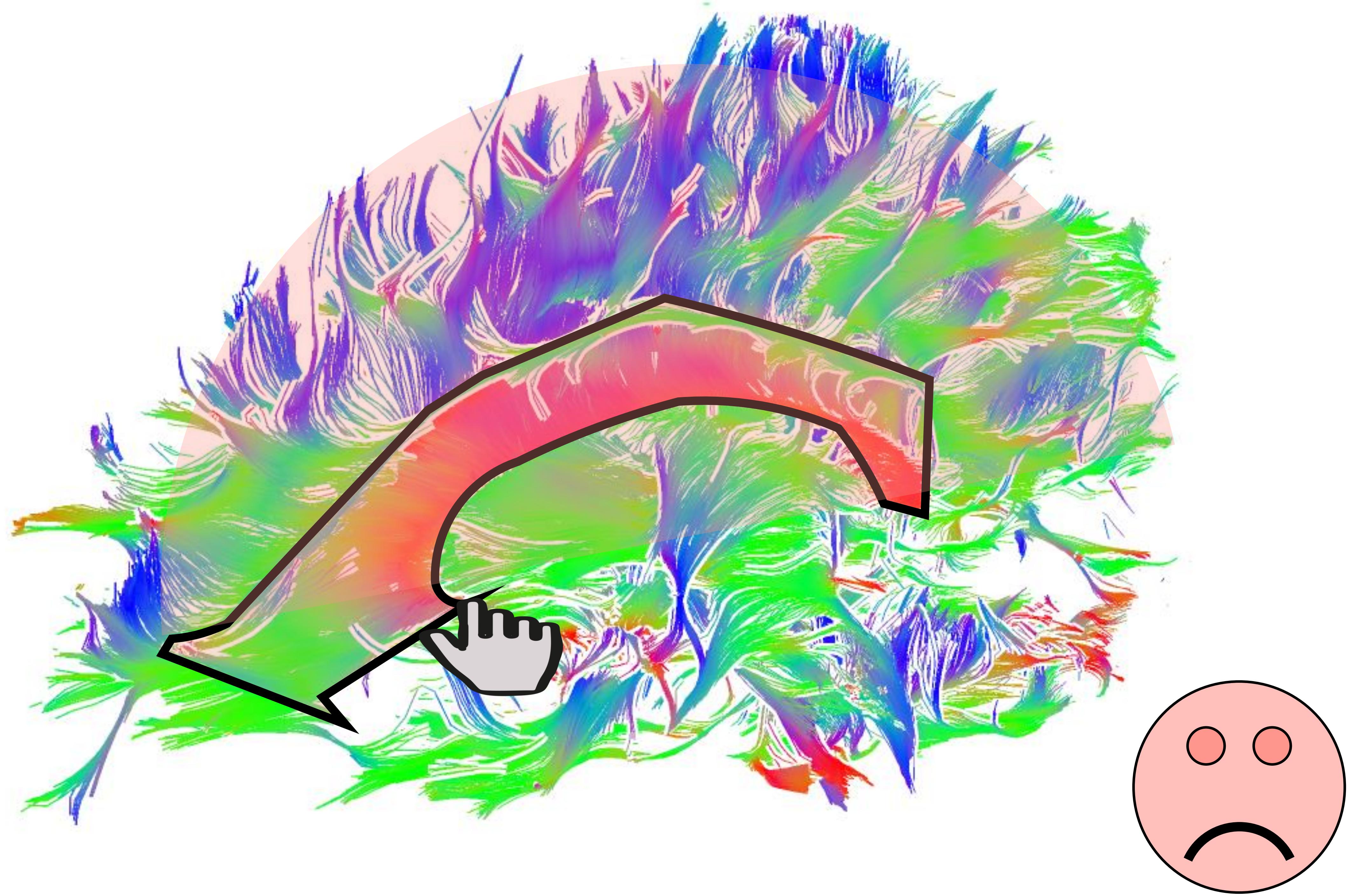


Selection by lasso, based on precise lasso shape

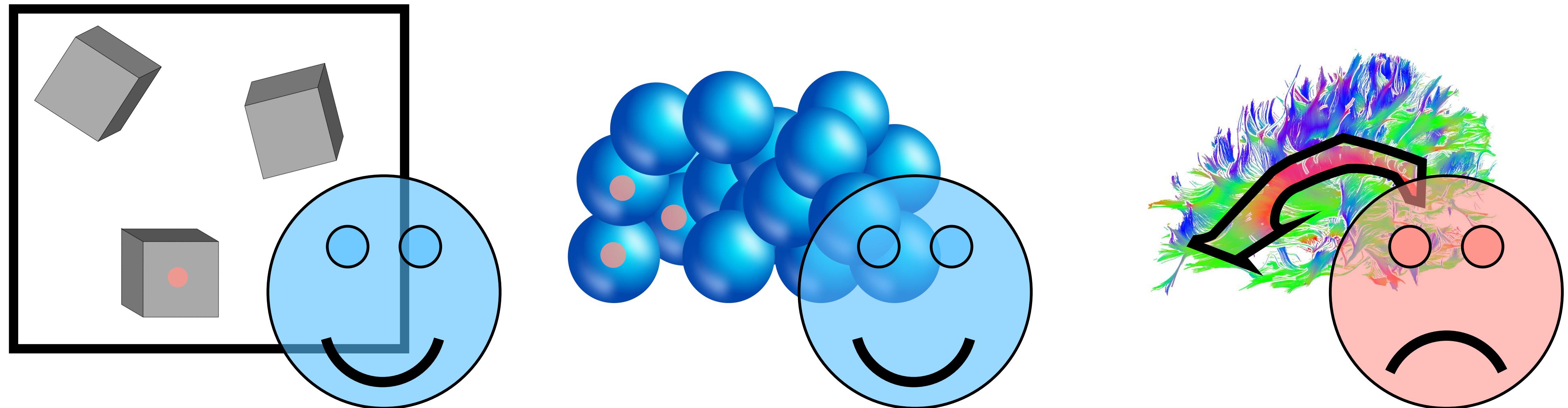








Lasso



Lasso



Lasso

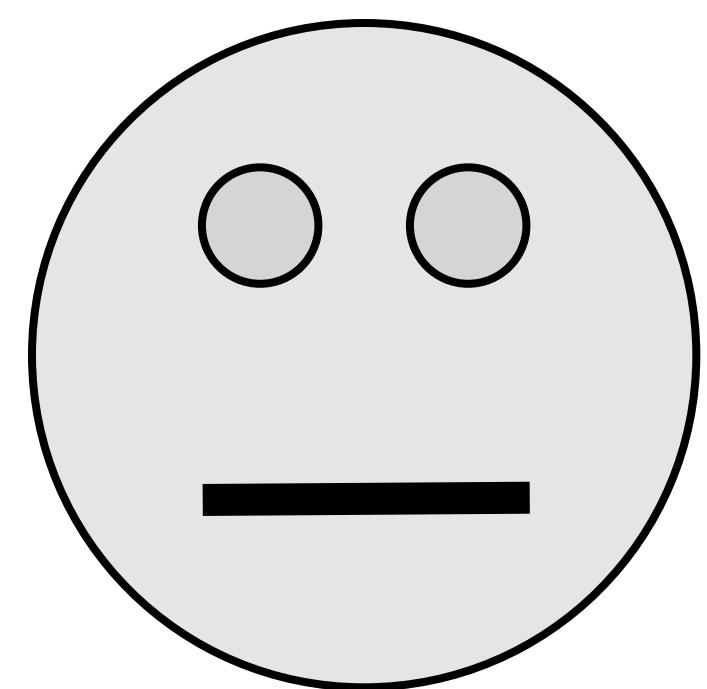
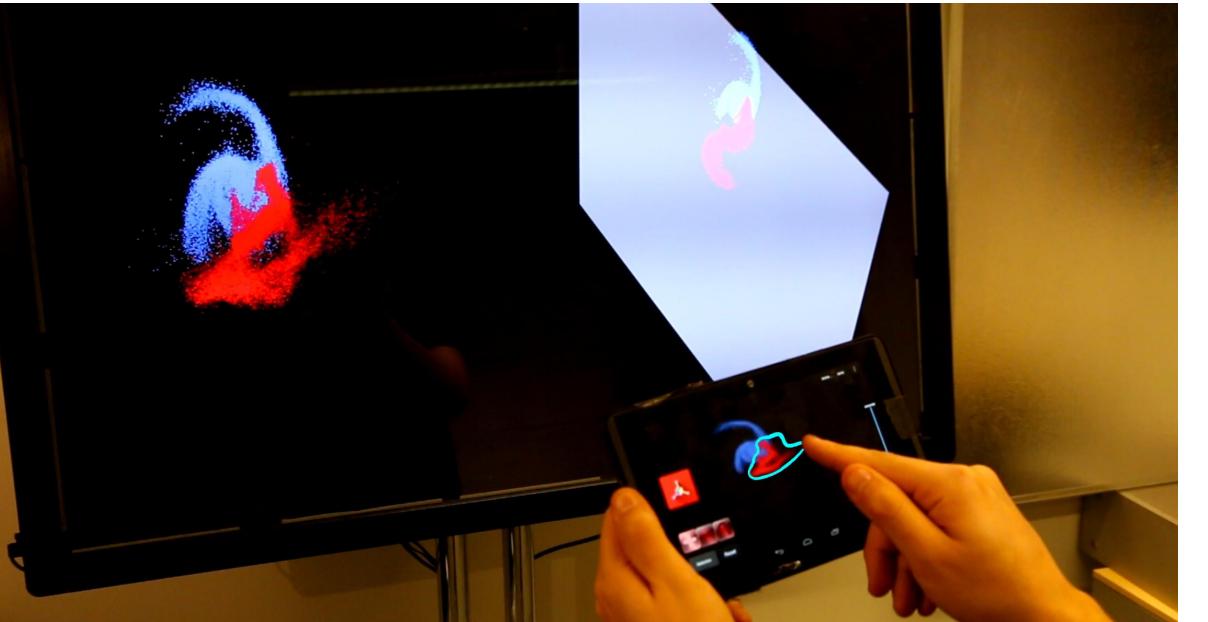


Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

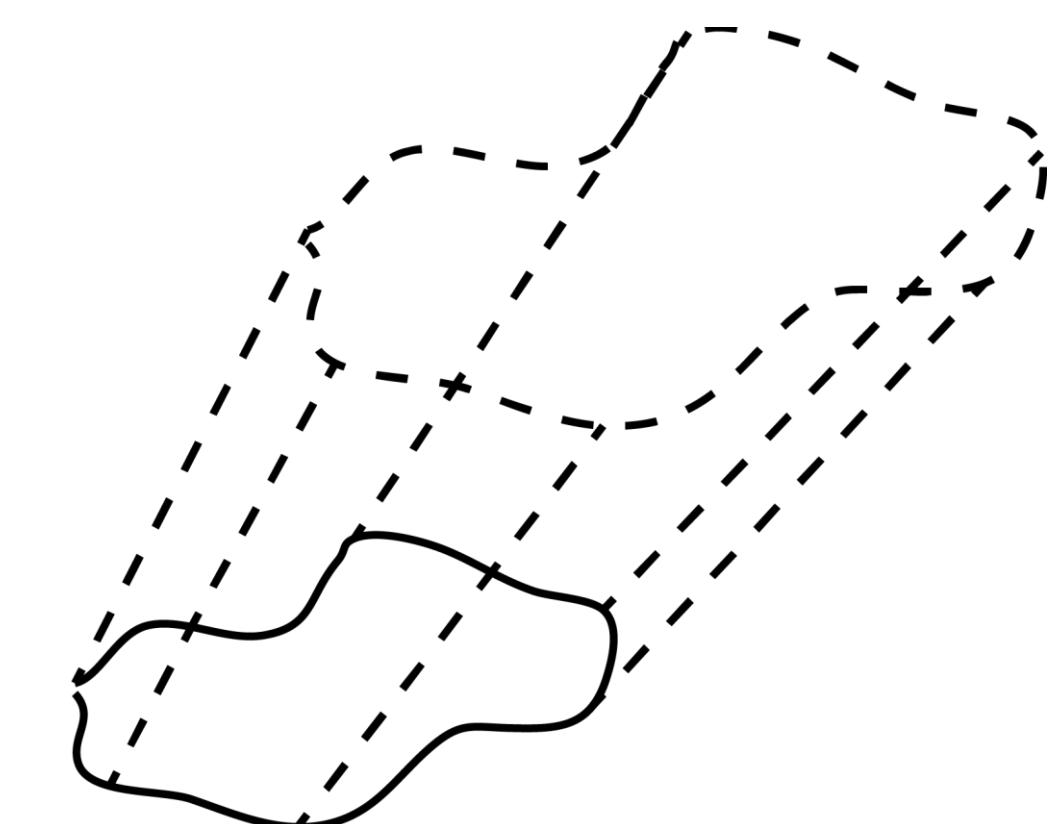
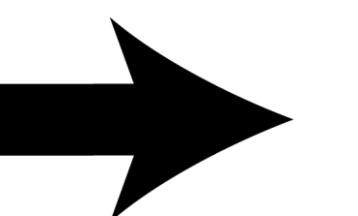
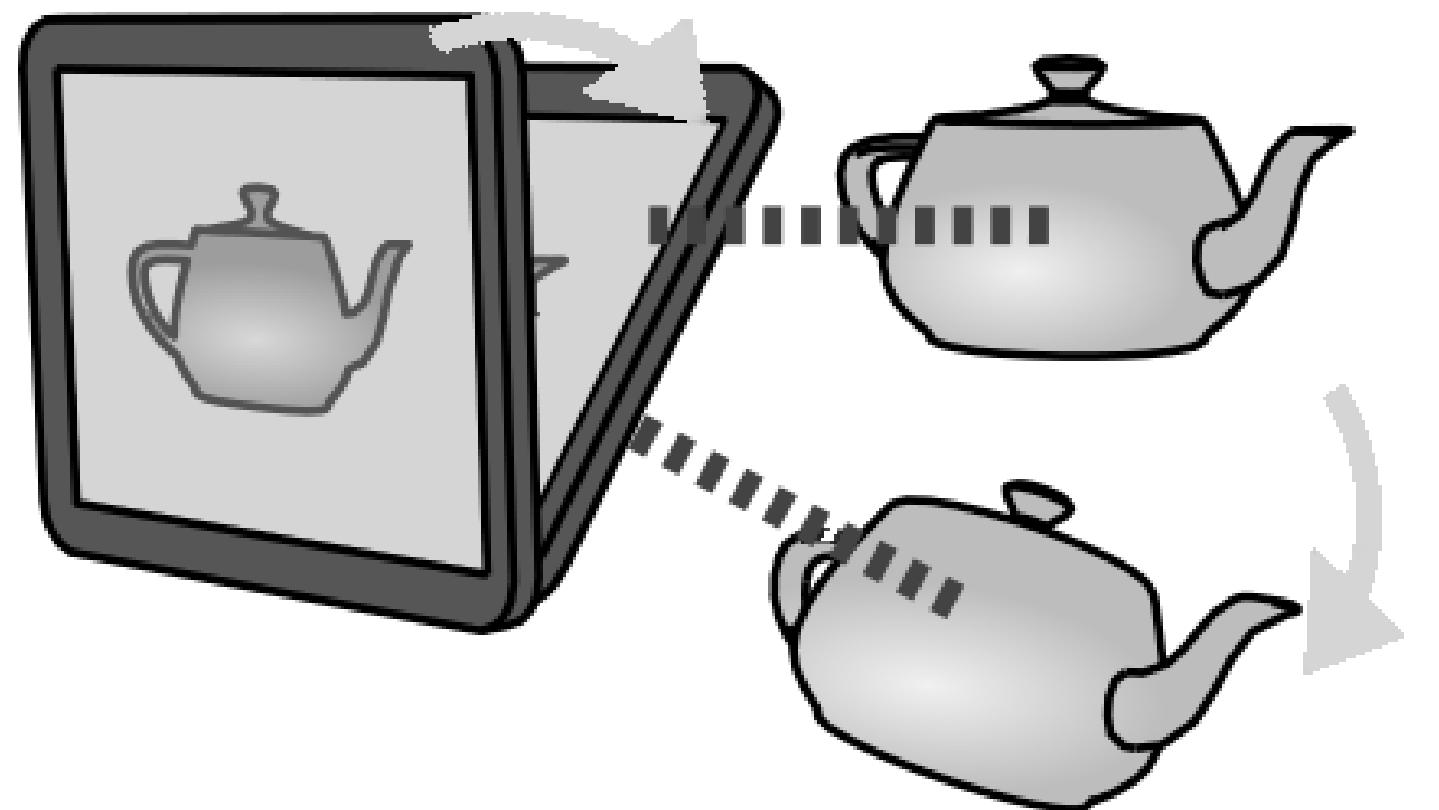
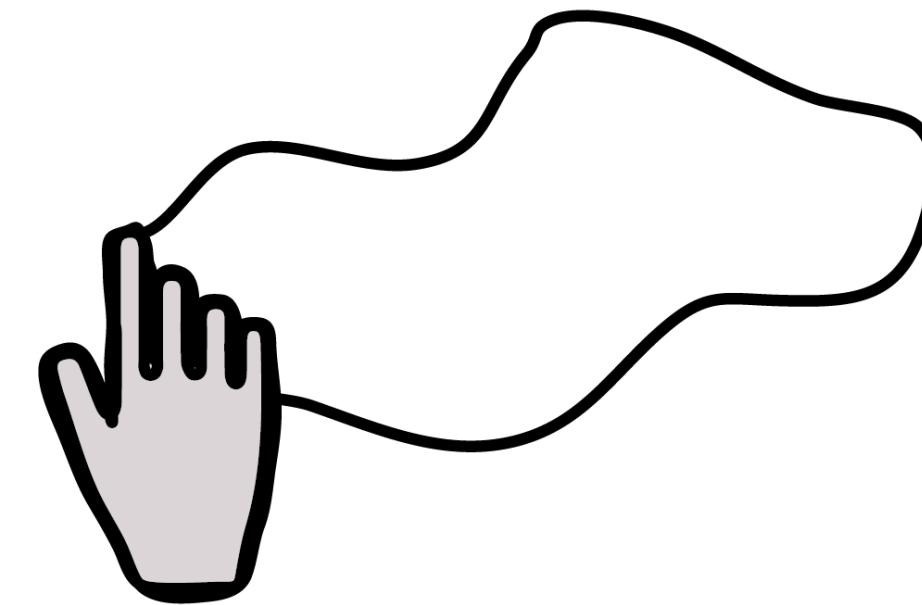
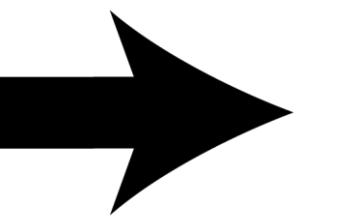
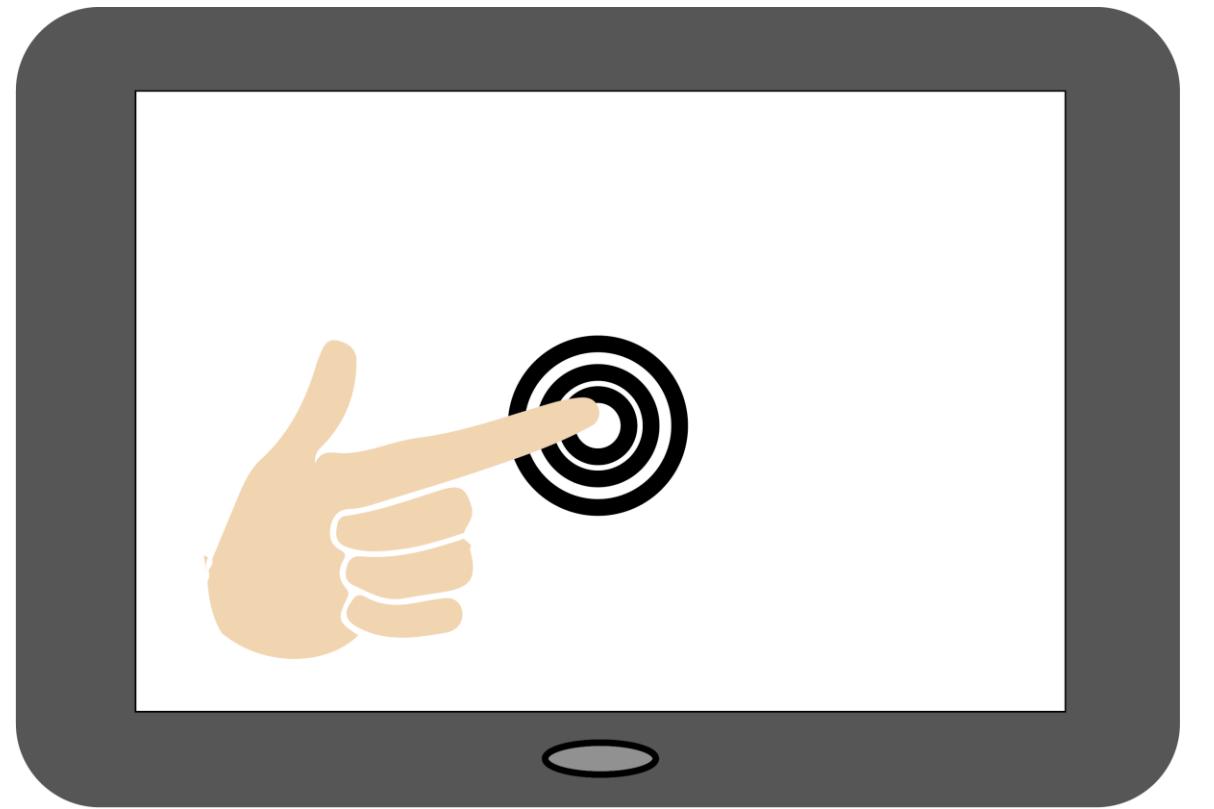
technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBWI96]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual

Table 2: Our taxonomy applied to a selection of techniques to illustrate the design space exploration of control.

technique	metaphor	target	shape creation	shape adjustment	selection DOF	input DOF	CD control
Balloon Selection [DFK12]	sphere	object	no control	no control	3 DOF	2 DOF	none
Go-Go [PBW196]	hand avatar	object	no control	no control	3 DOF	6 DOF	none
RayCasting [Min95]	ray	object	no control	no control	5 DOF (trans.: 3, rot.: 2)	up to 6 DOF	none
Framing Hands [PFC*97]	ray	object(s)	no control	no control	5 DOF	6 DOF	none
iSith [WBB06]	ray	object	no control	no control	5 DOF	12 DOF (2 hands)	none
Flexible Pointer [OF03]	curved ray	object	no control	no control	10 DOF	12 DOF (2 hands)	none
Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6 DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6 DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6 DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom.	2D input	no control	2 DOF	2 DOF
CloudLasso [YEH12]	lasso	ROI	semi-autom.	2D input	threshold adjust.	2 DOF	2 DOF
CAST [YEH16]	lasso	ROI	semi-autom.	2D input	threshold adjust.	2 DOF	2 DOF
Tangible Brush	lasso + extrusion	ROI/objects	manual	none	up to 6 DOF	up to 6 DOF	manual

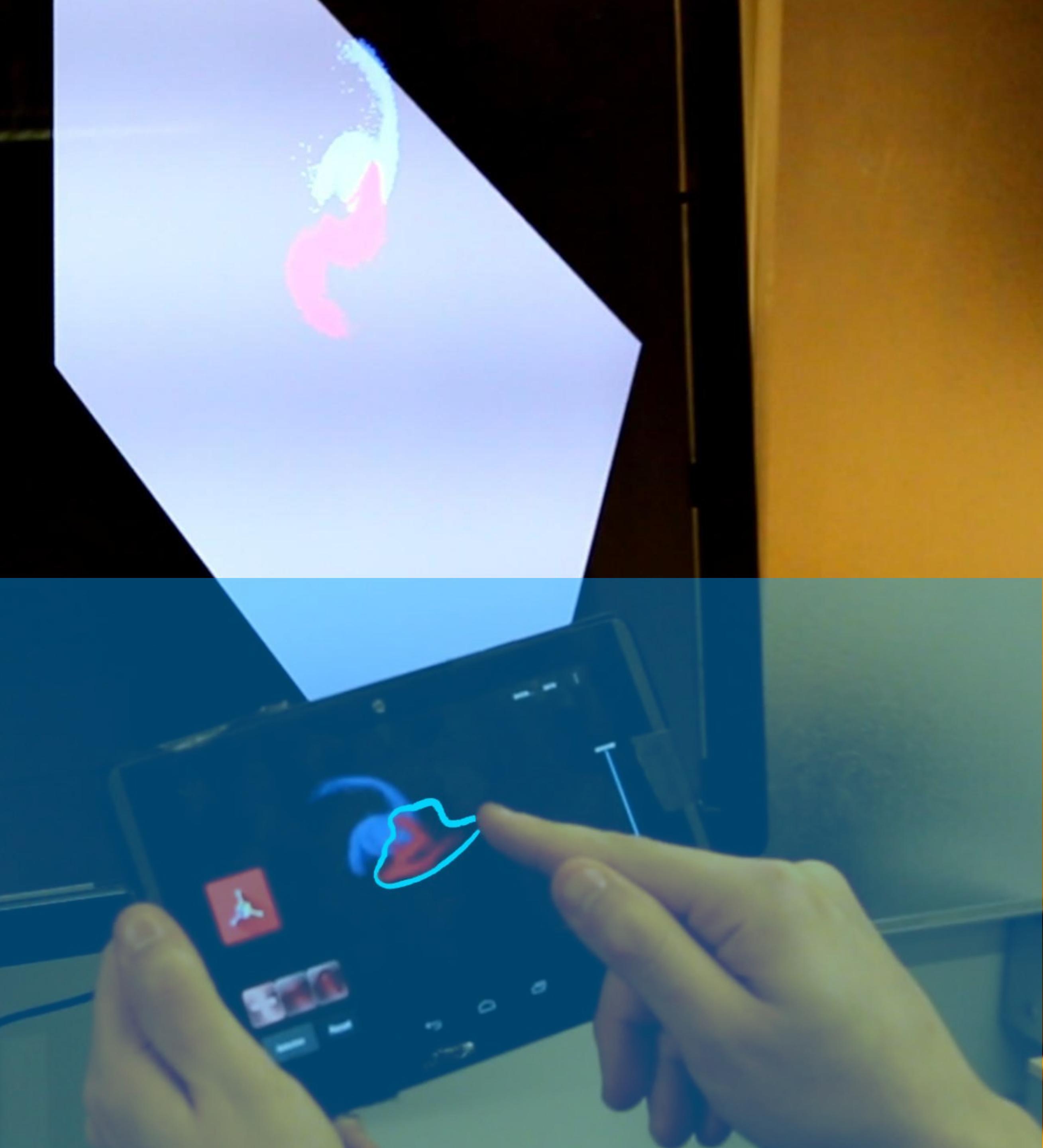


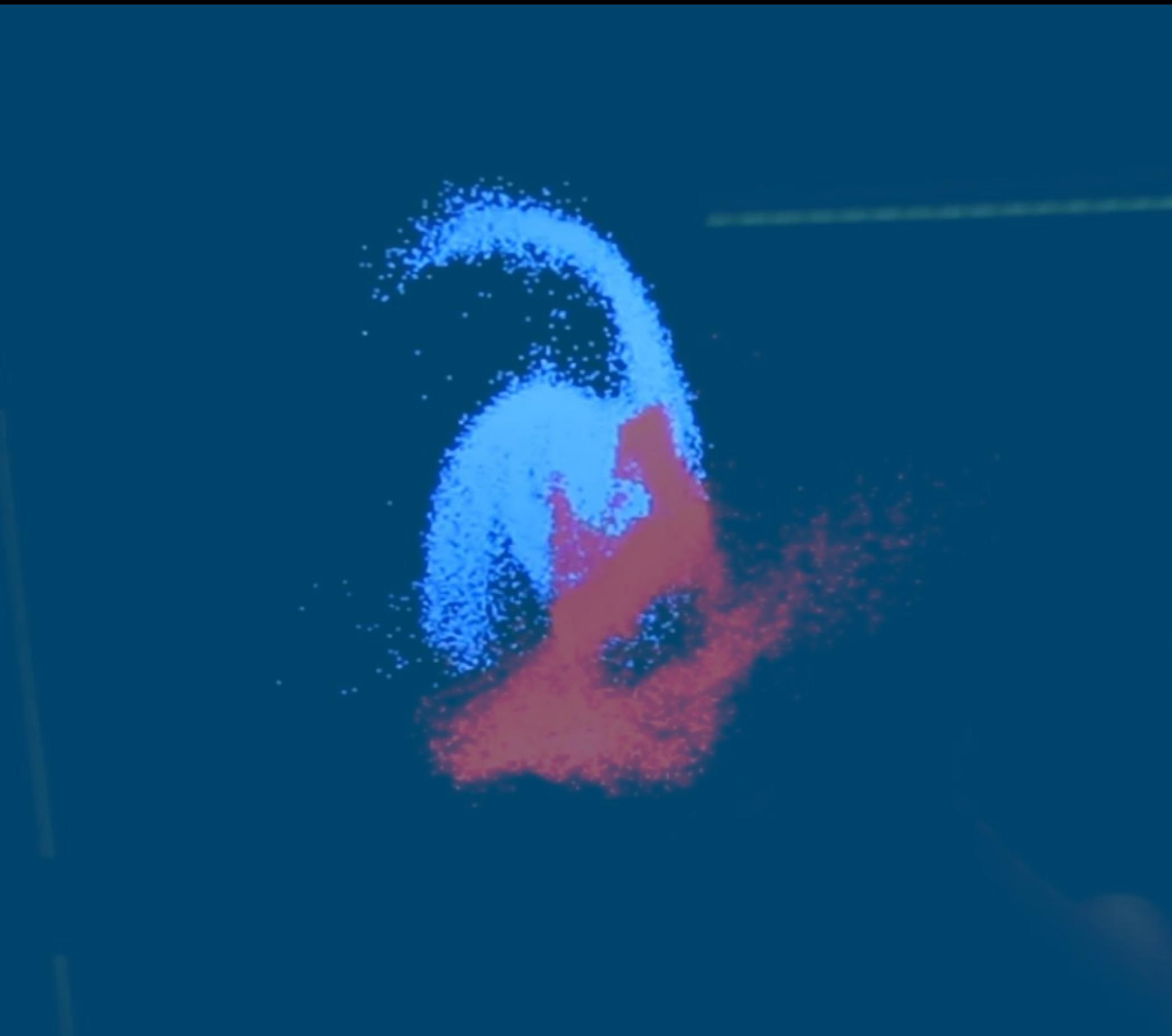
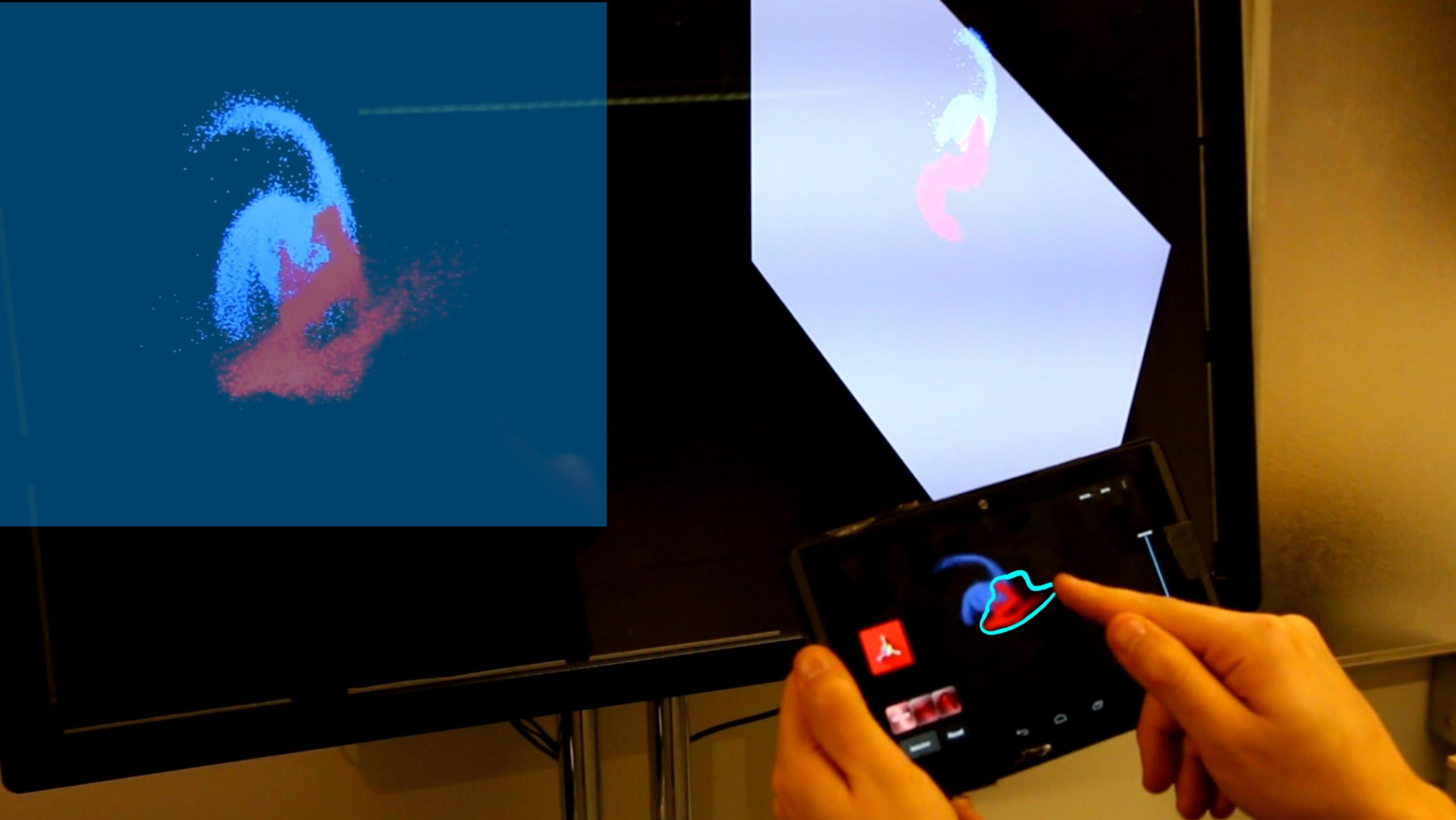


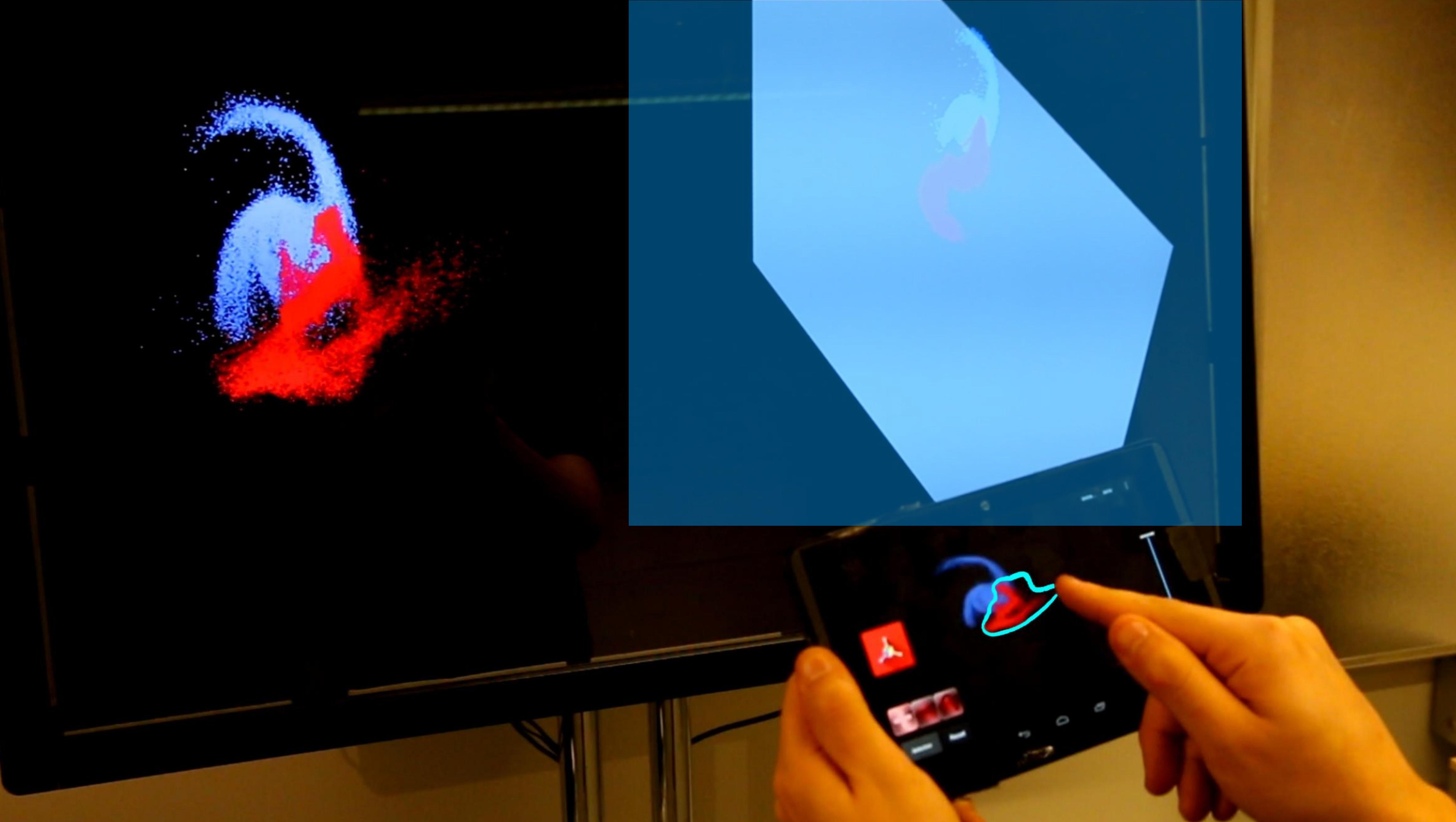


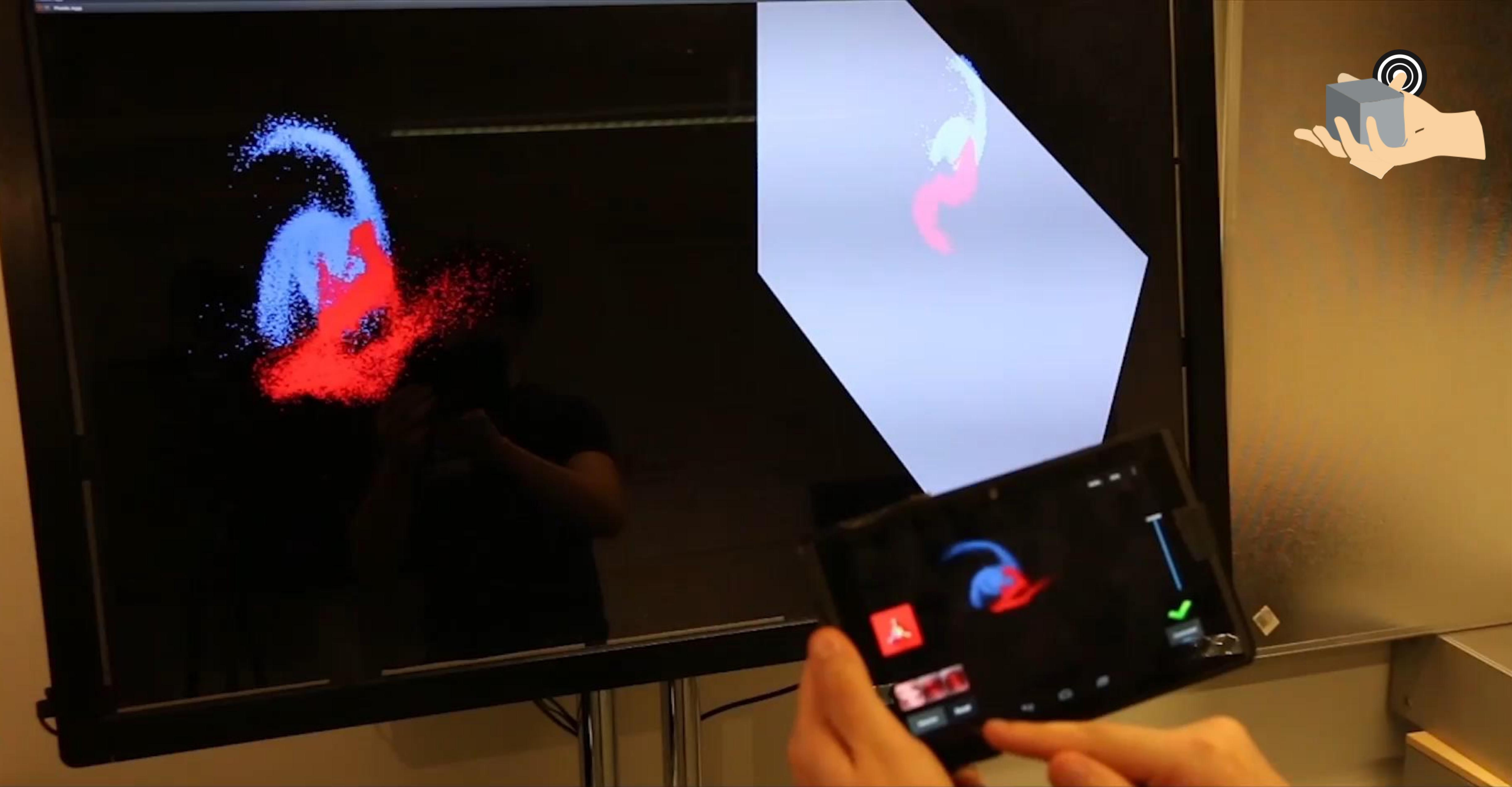










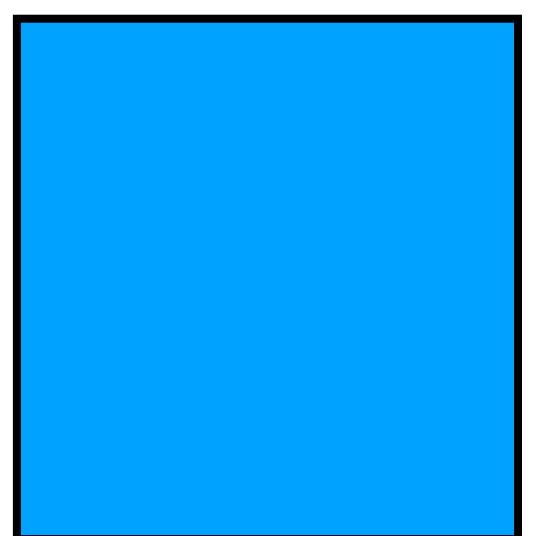


To start a selection, the user switches the mode

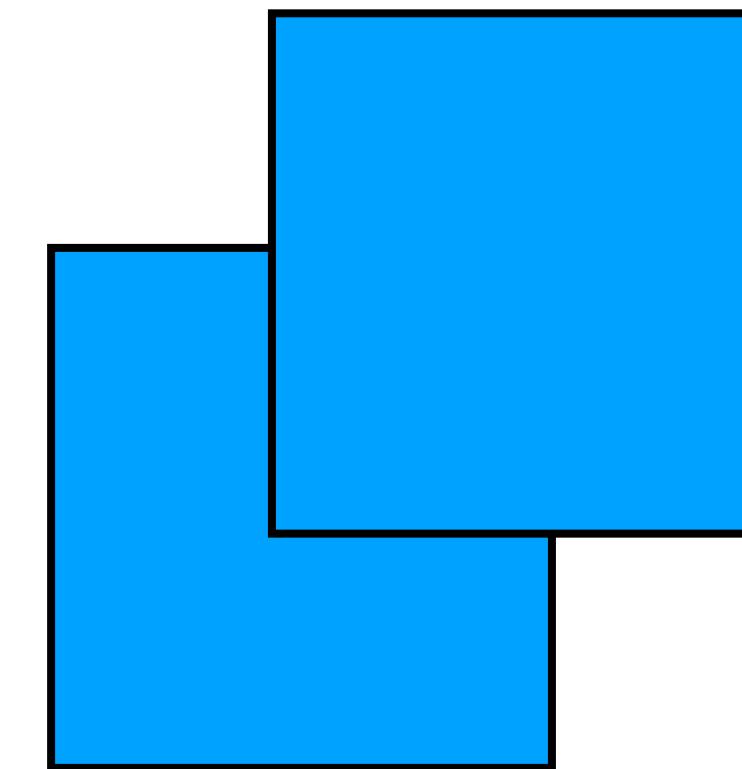
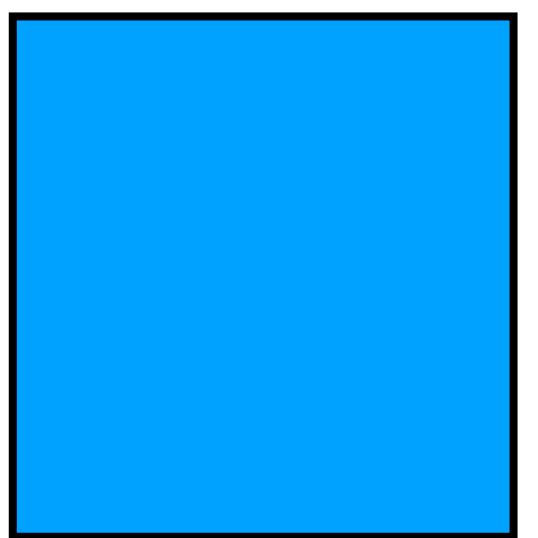


or unconstrained to consider all 6DOF motions of the device.

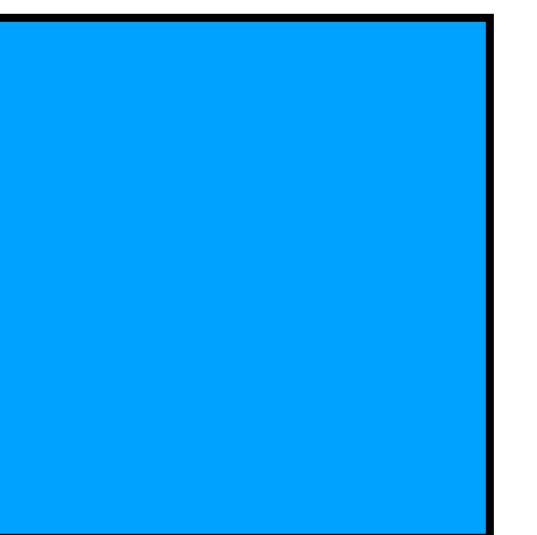
OR



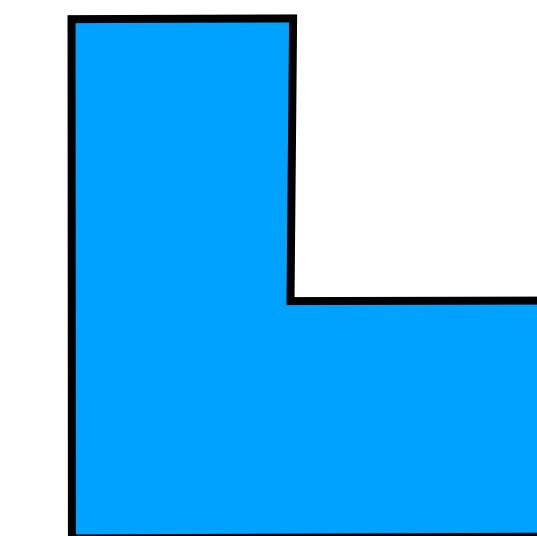
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AND NOT



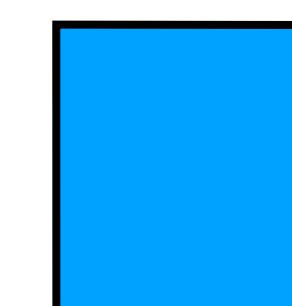
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AND



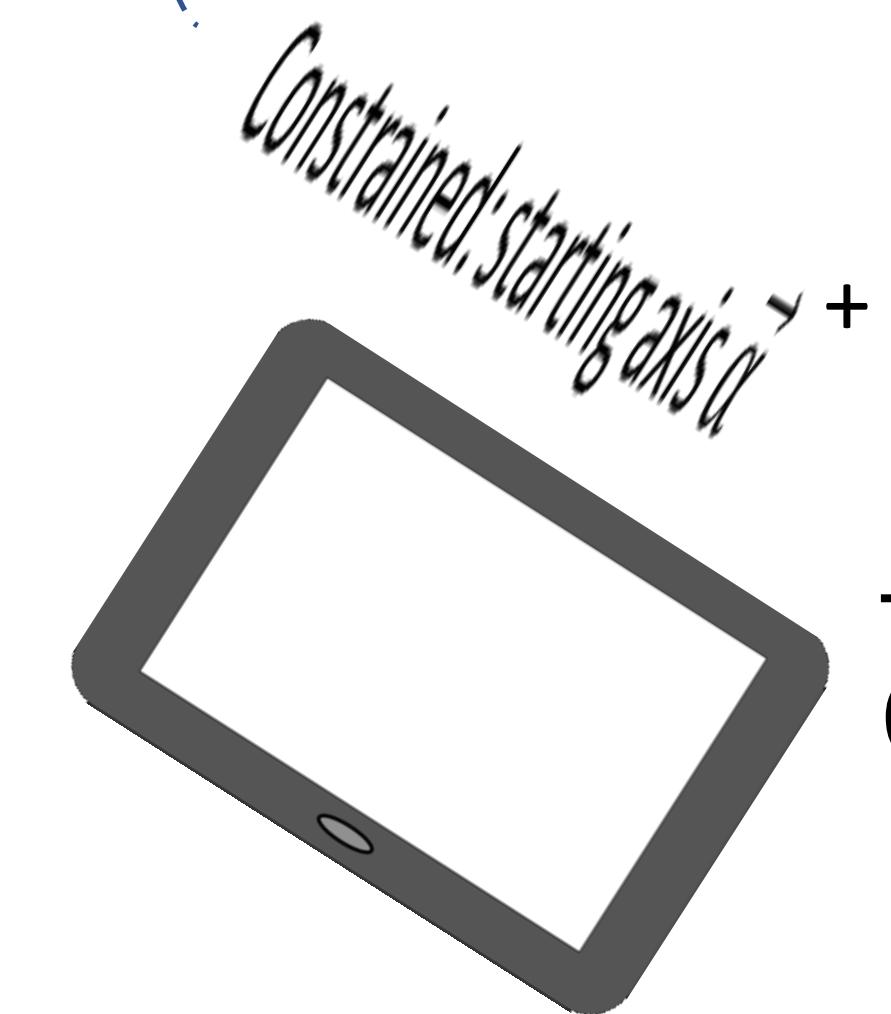
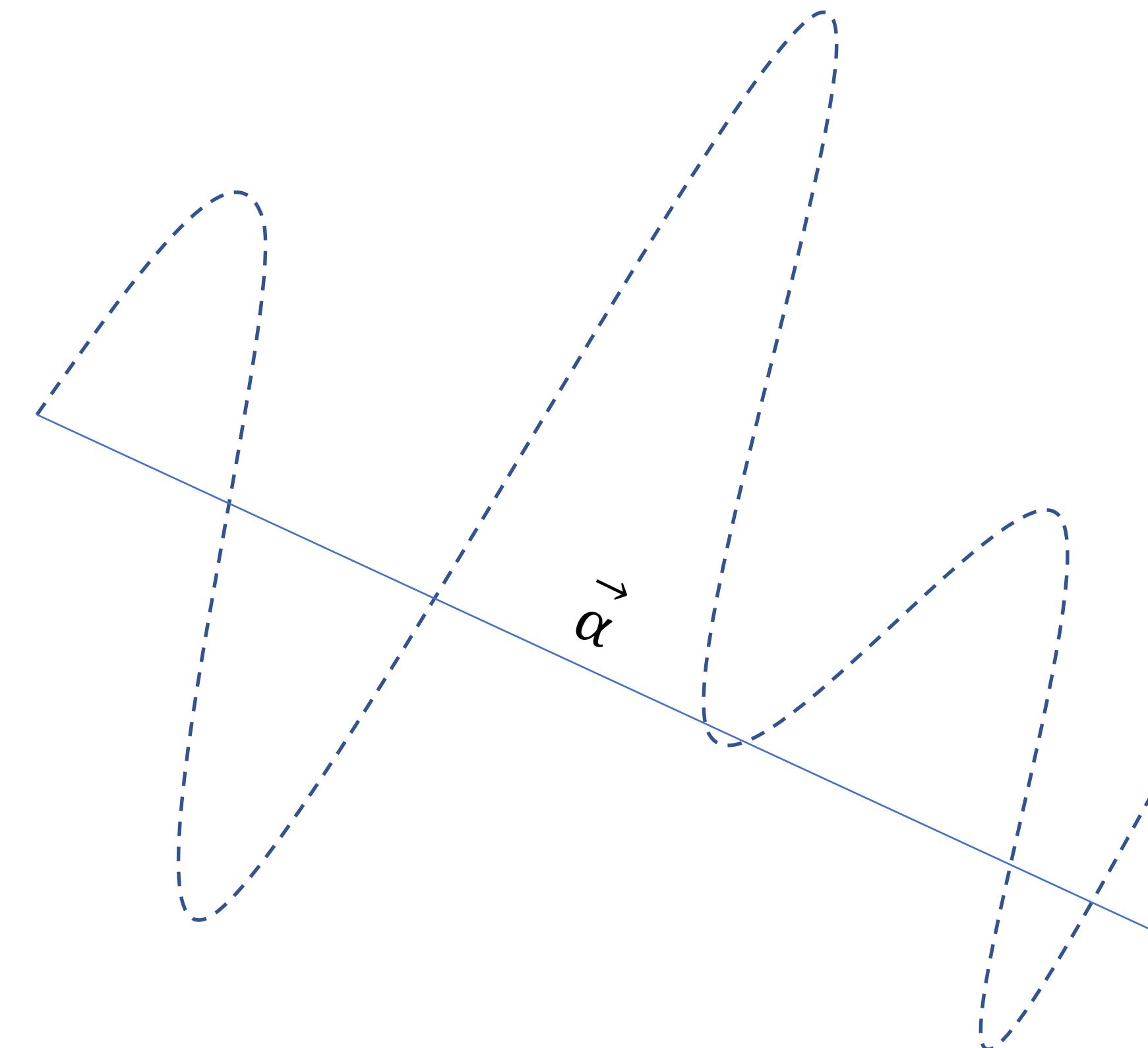
\wedge



Constrained: starting axis



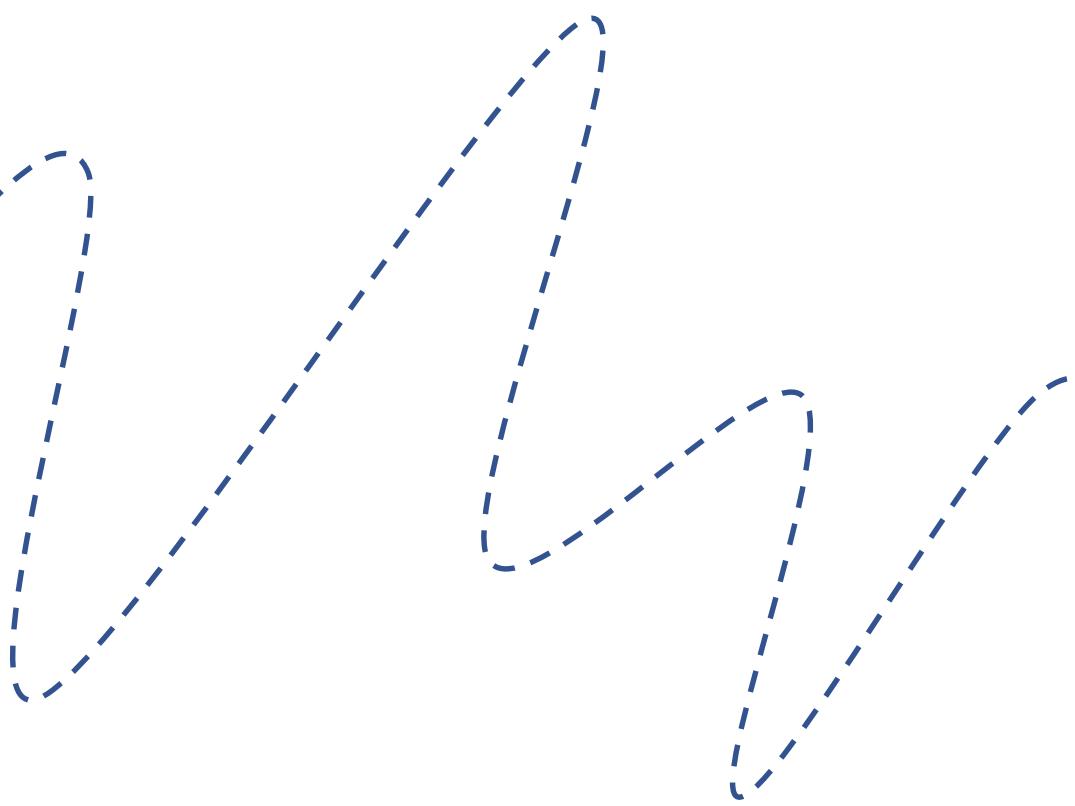
$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$$



$$\vec{\alpha} + \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

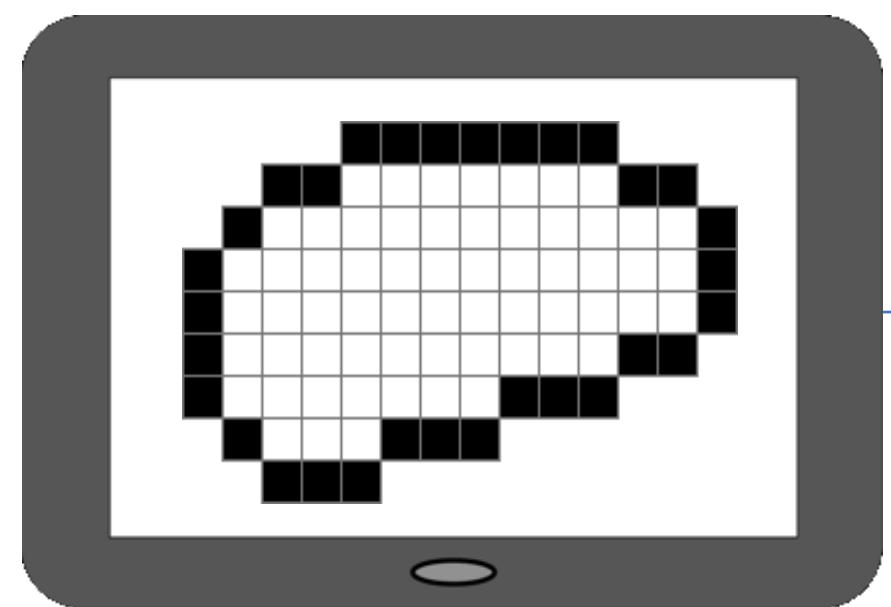


$$MVP = \begin{pmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ m & o & p & q \end{pmatrix}$$

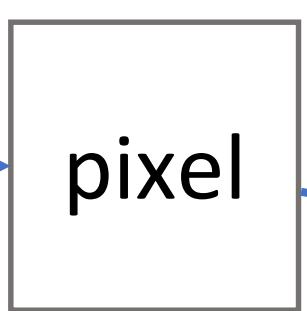


$$MVP = \begin{pmatrix} a' & b' & c' & d' \\ e' & f' & g' & h' \\ i' & j' & k' & l' \\ m' & o' & p' & q' \end{pmatrix}$$

2D Lasso

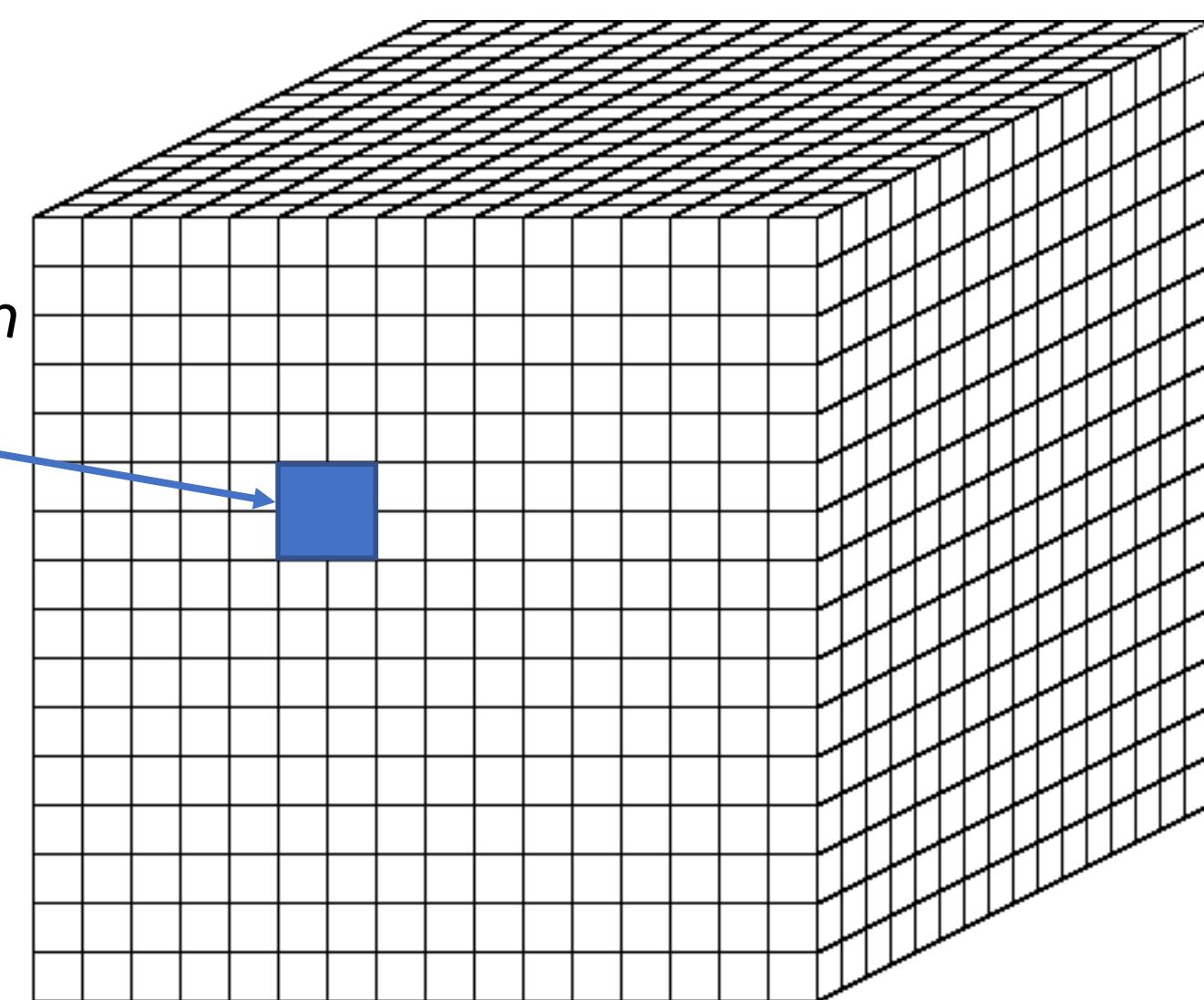


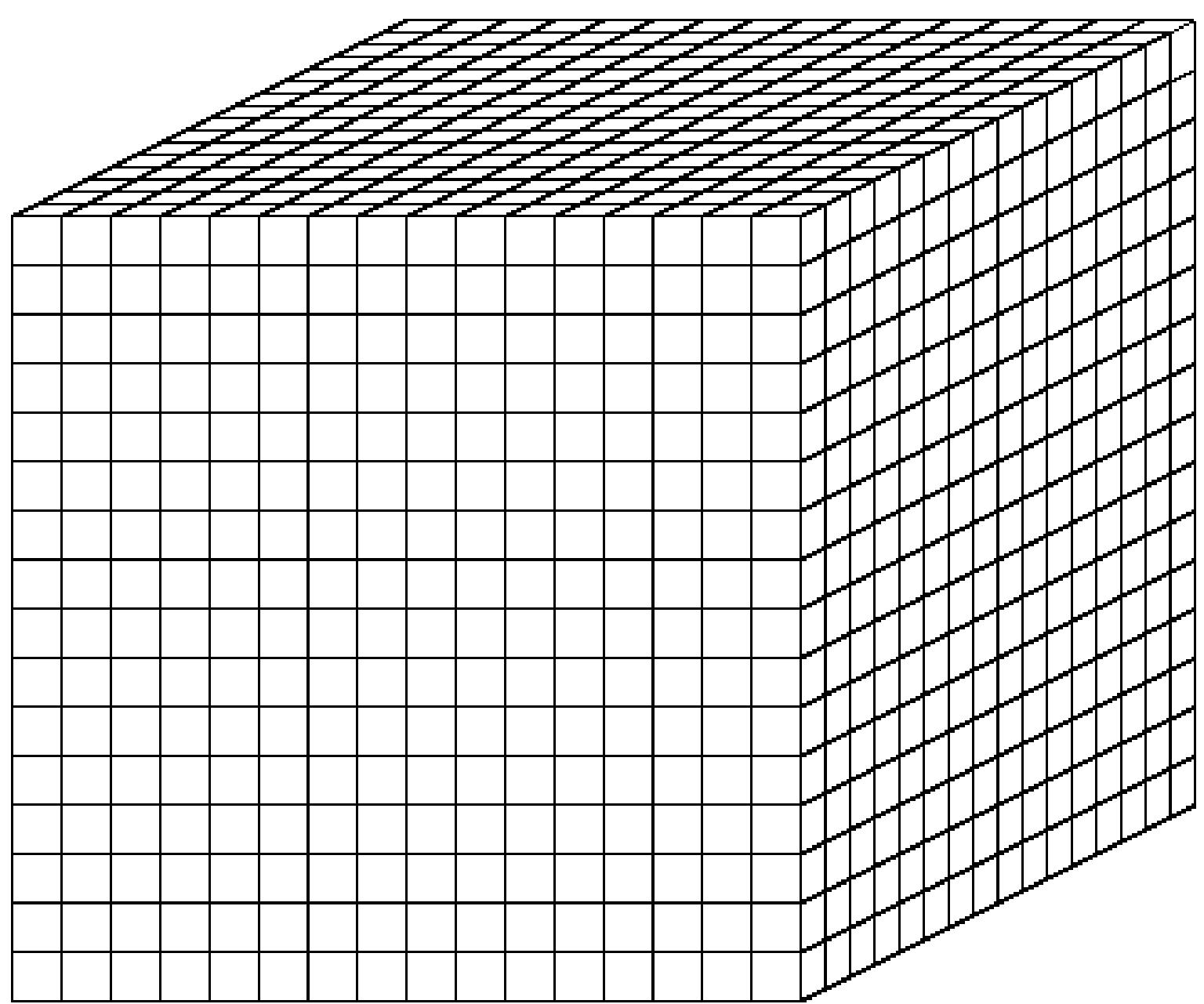
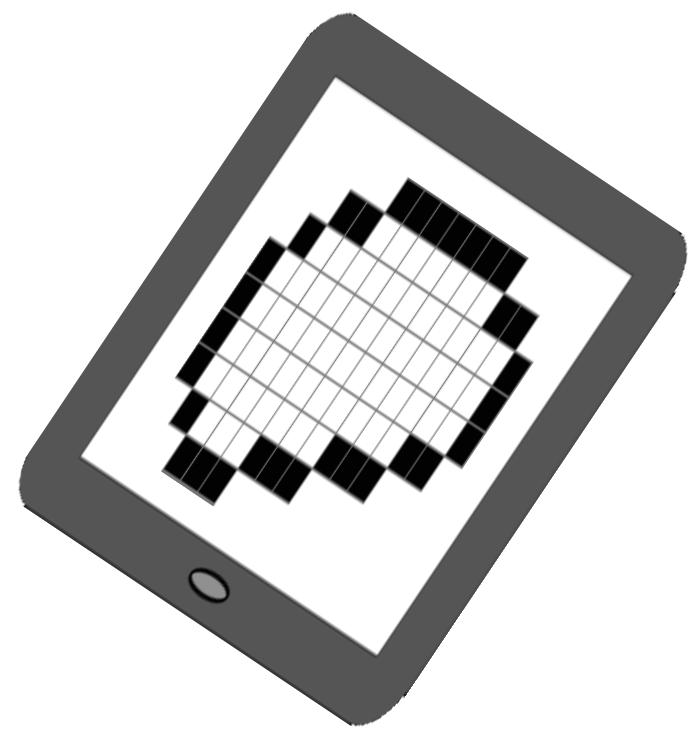
« 3D » size = 0,5 unit

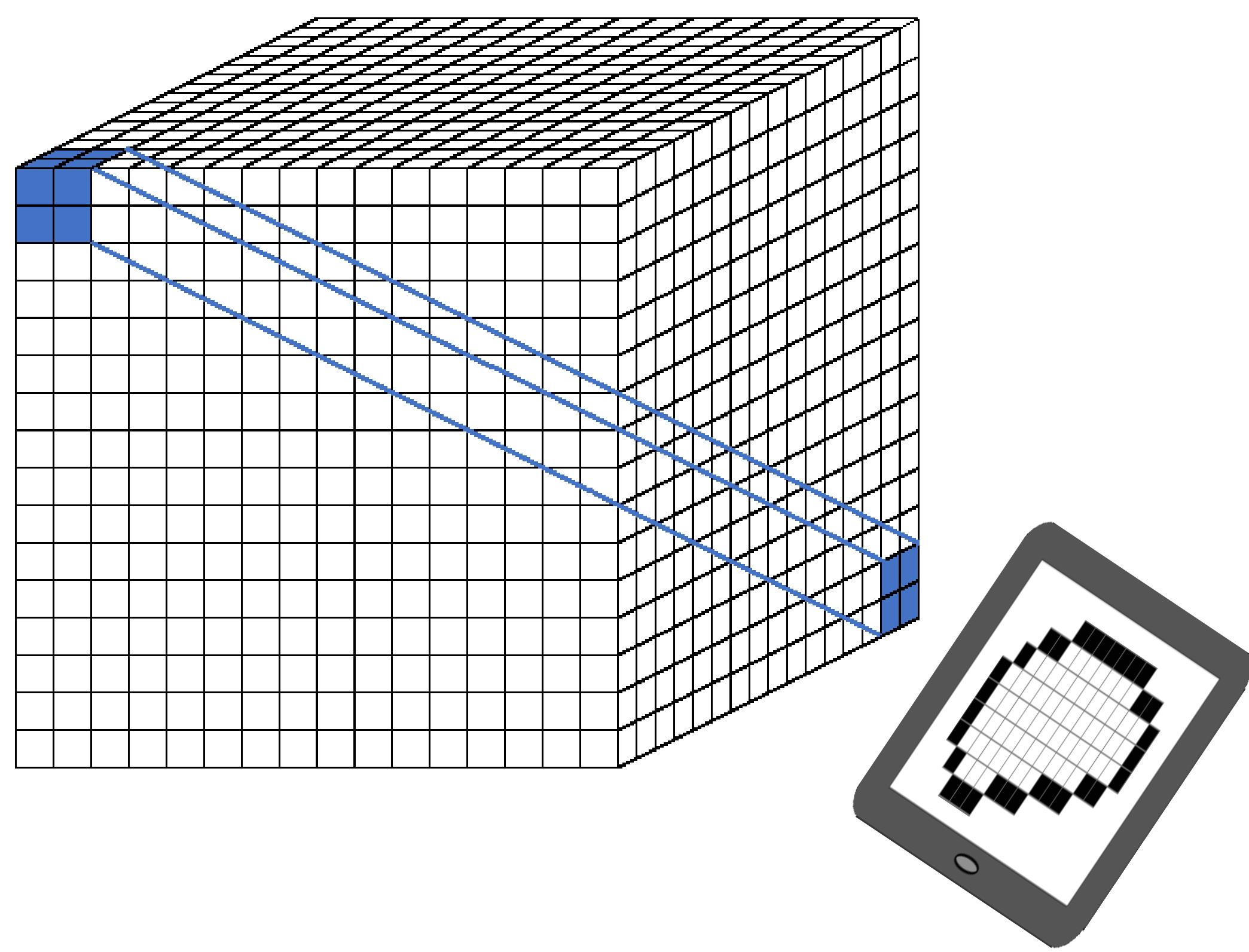


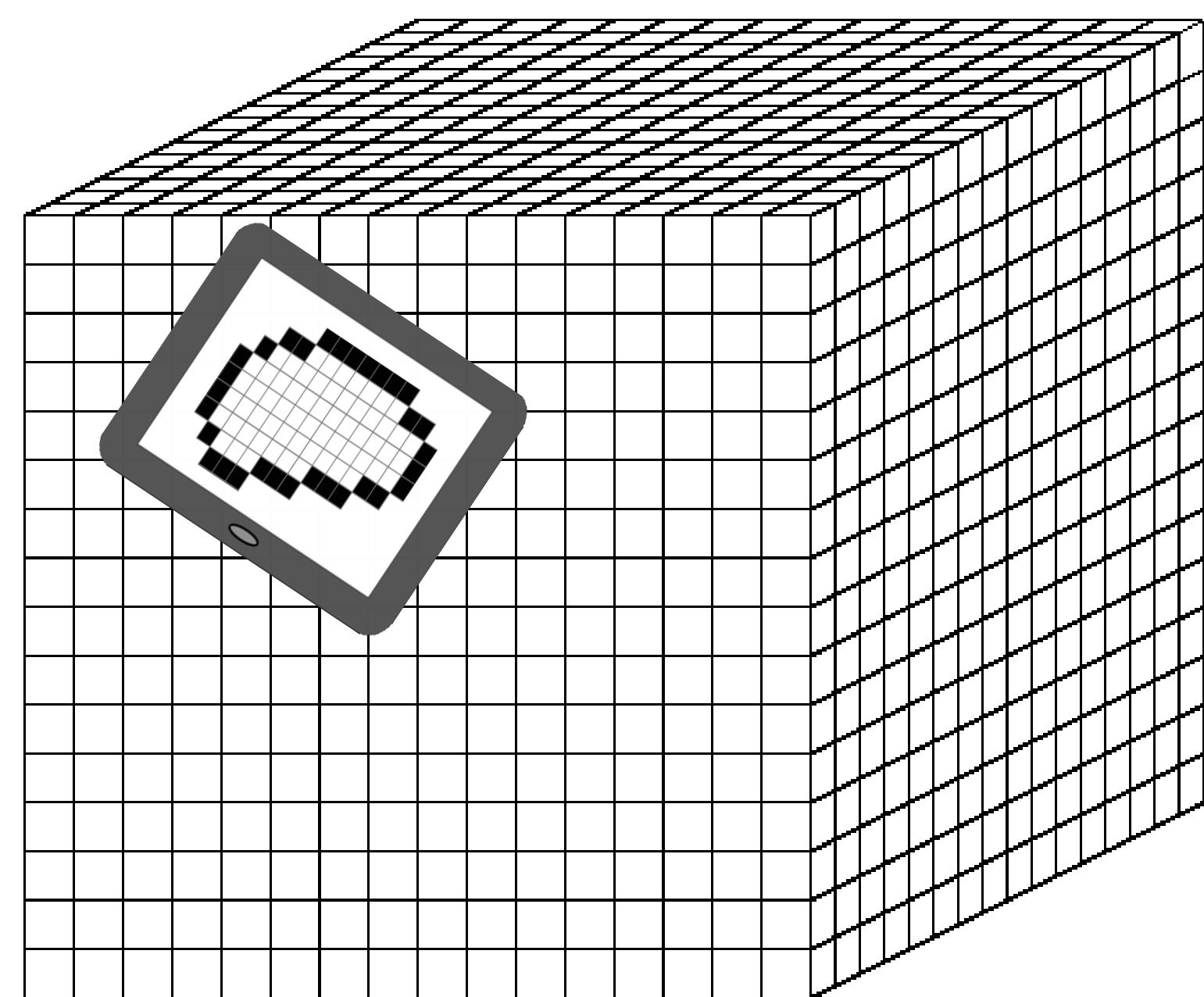
*Inverse Model-View-Projection
Matrix*

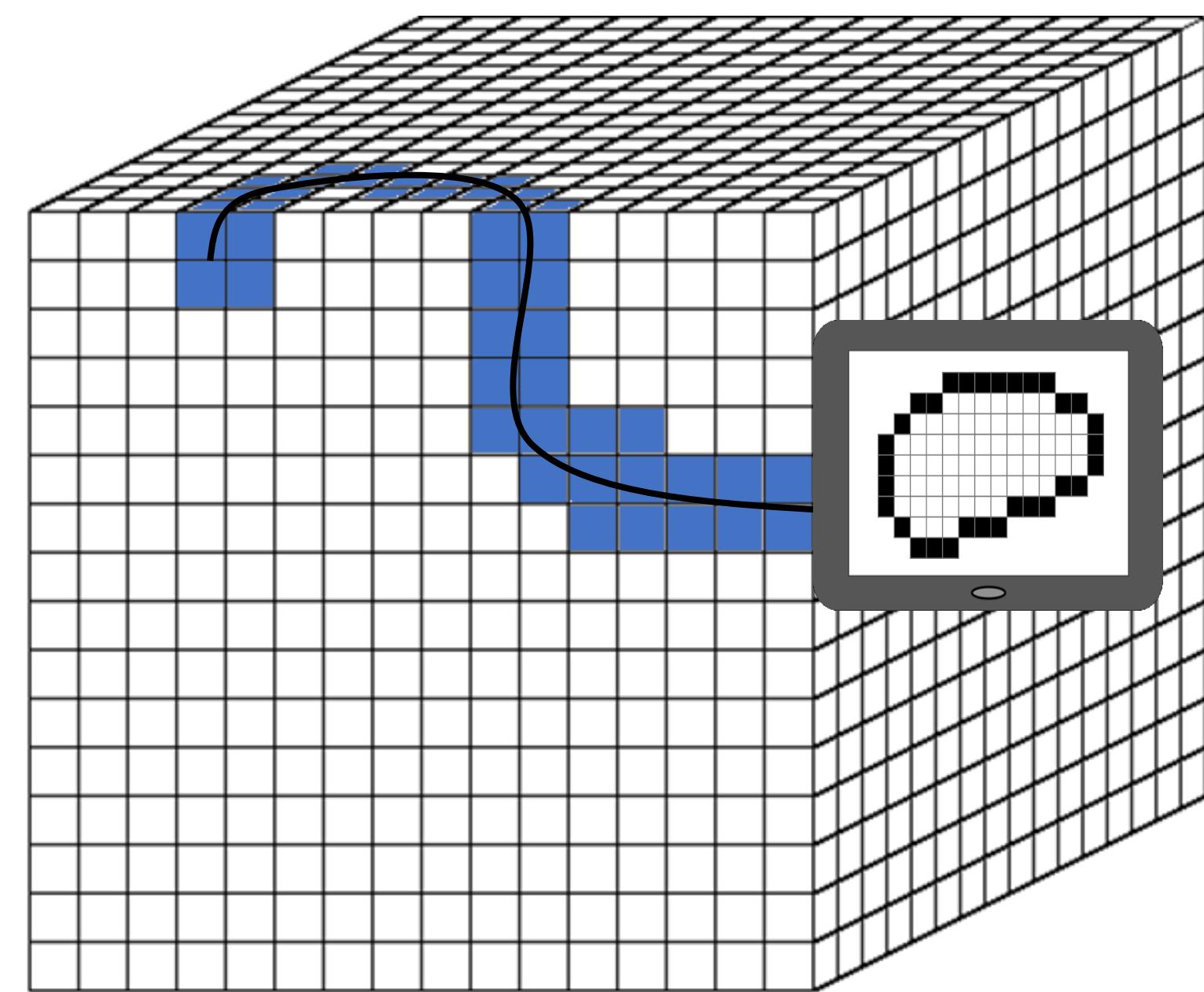
3D rasterized space

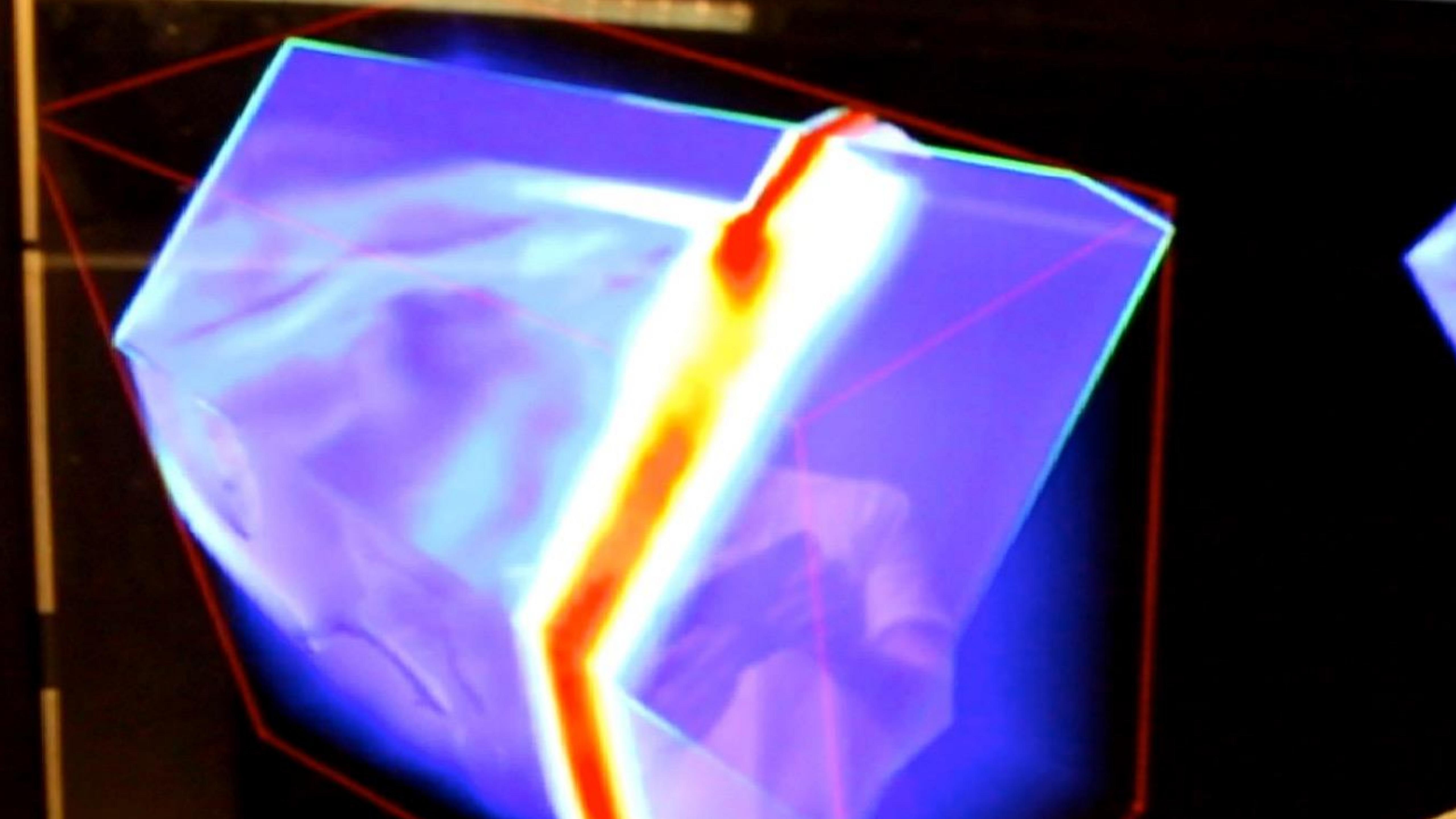












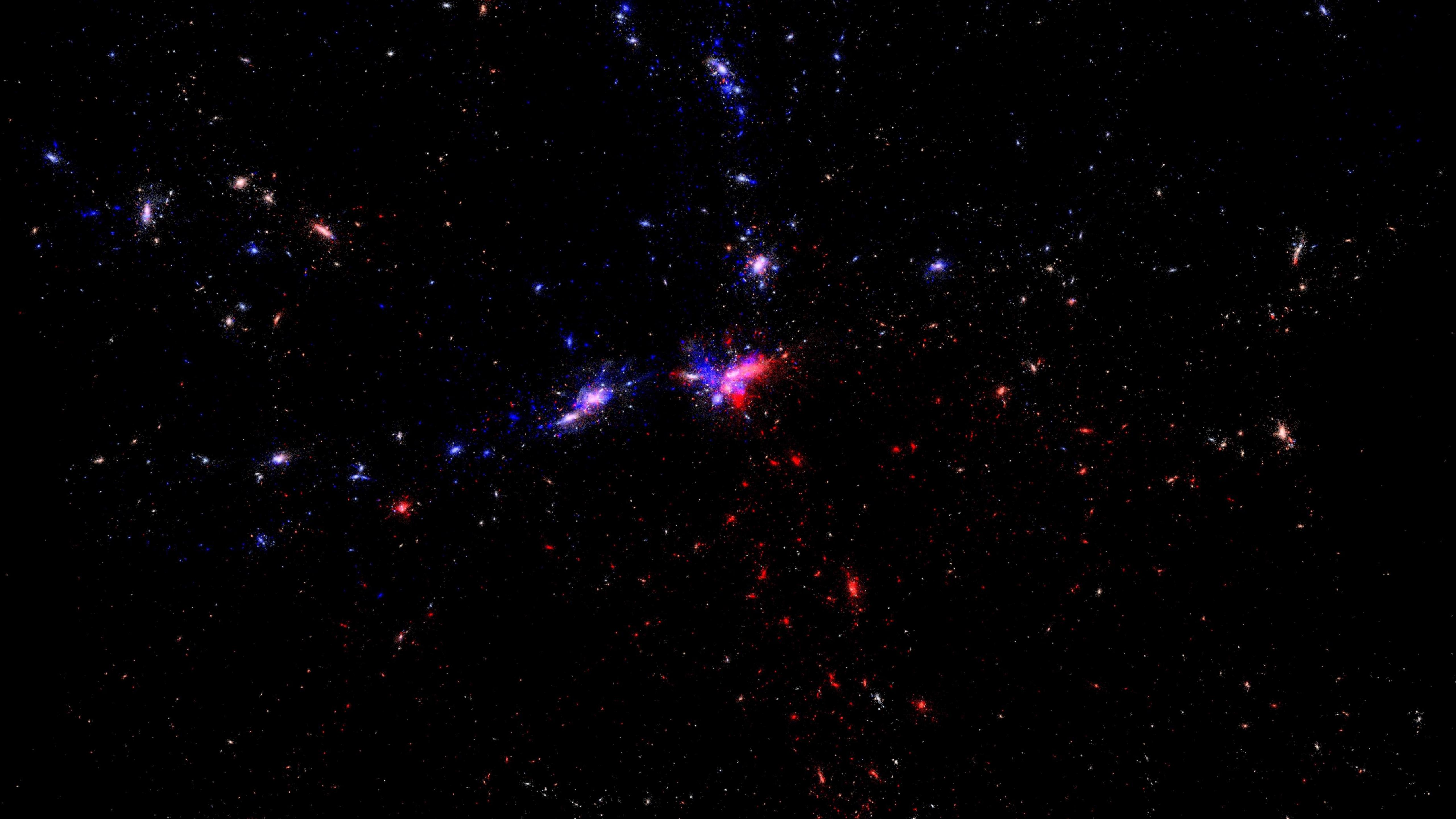
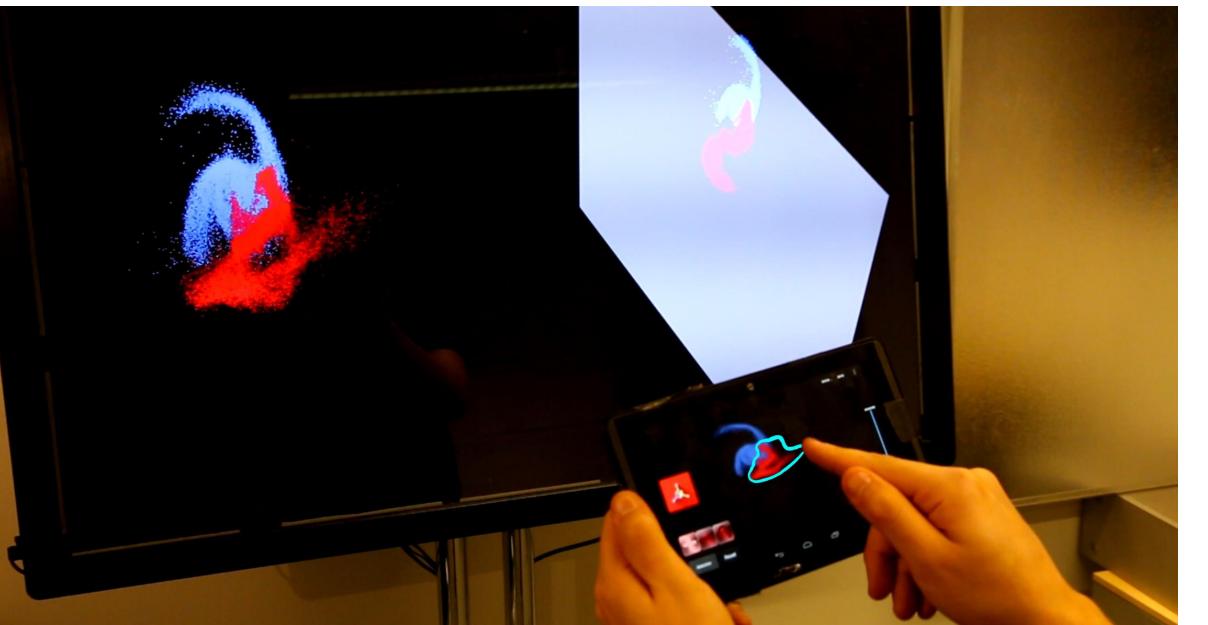
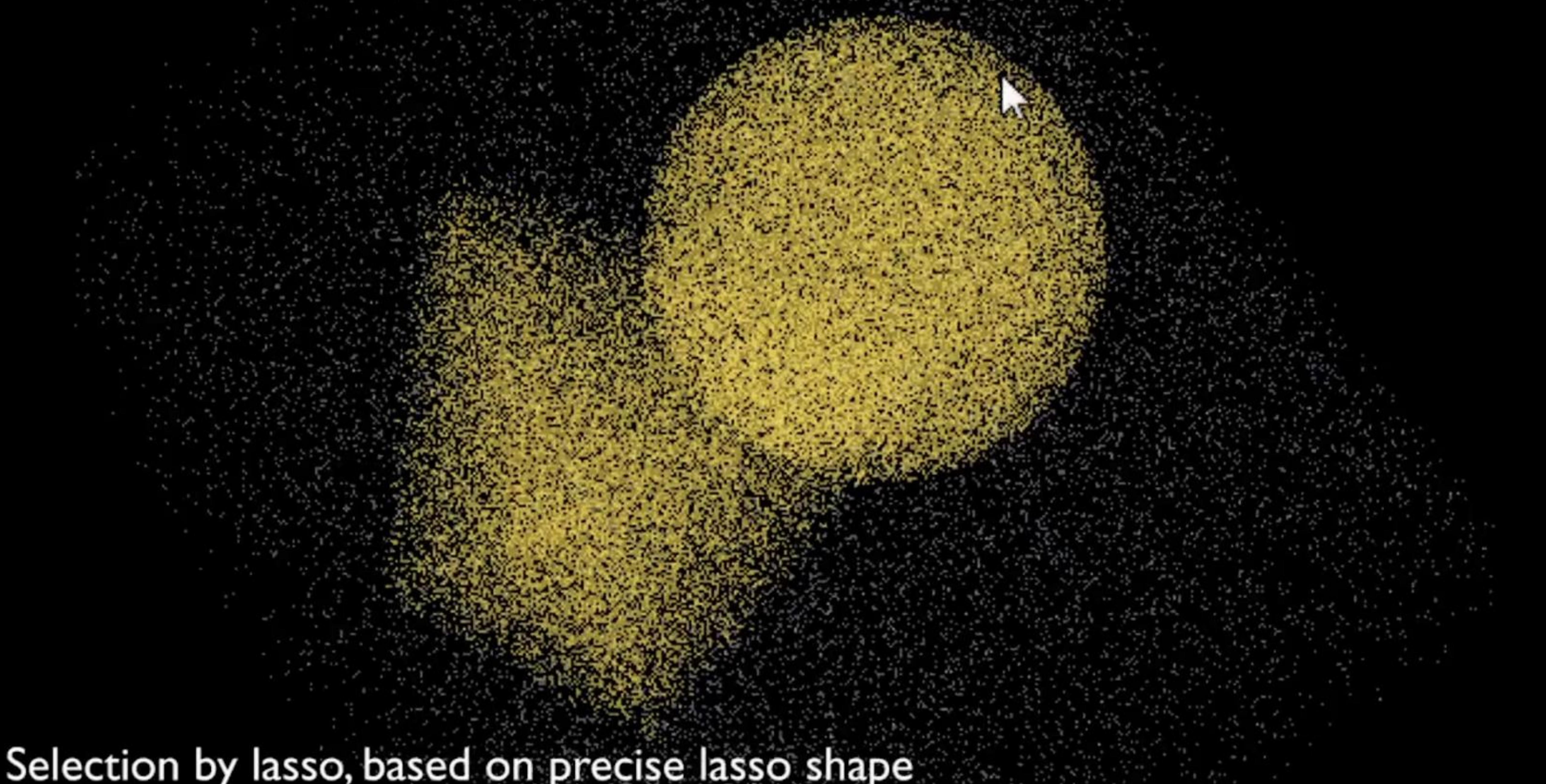


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Tangible Brush	lasso + extrusion	ROI/objects	manual	none	up to 6 DOF	up to 6 DOF	manual

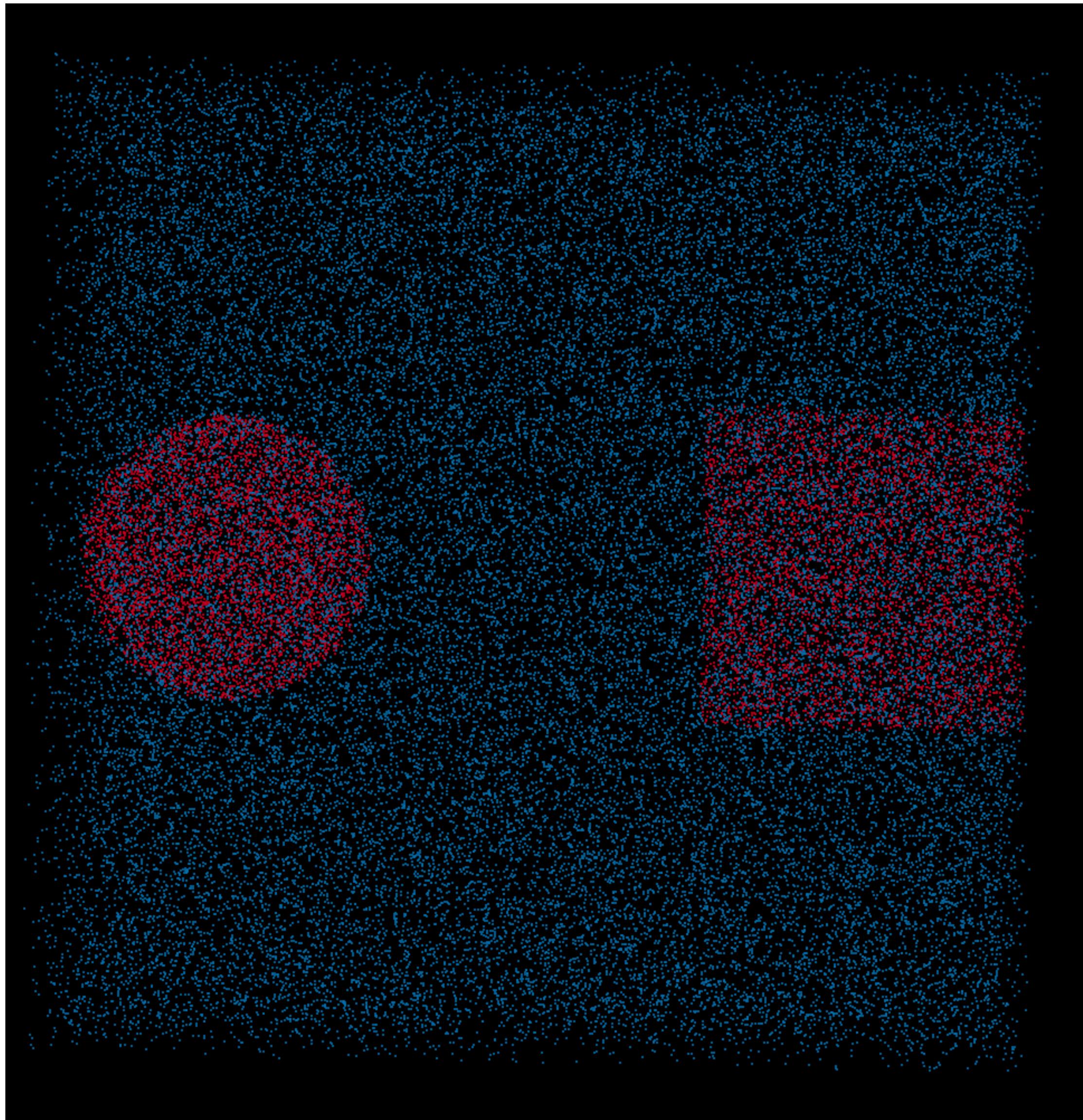




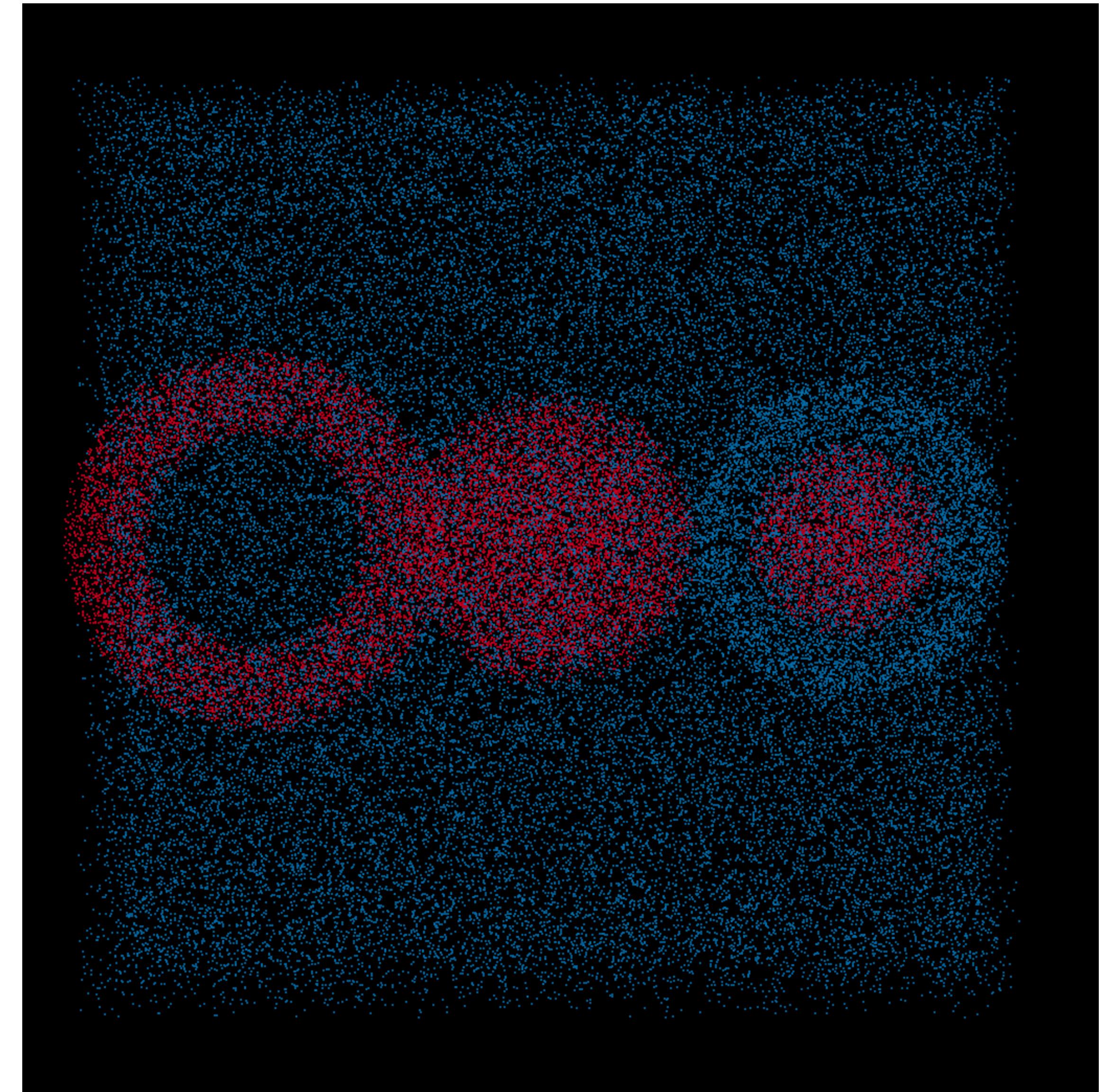


Selection by lasso, based on precise lasso shape

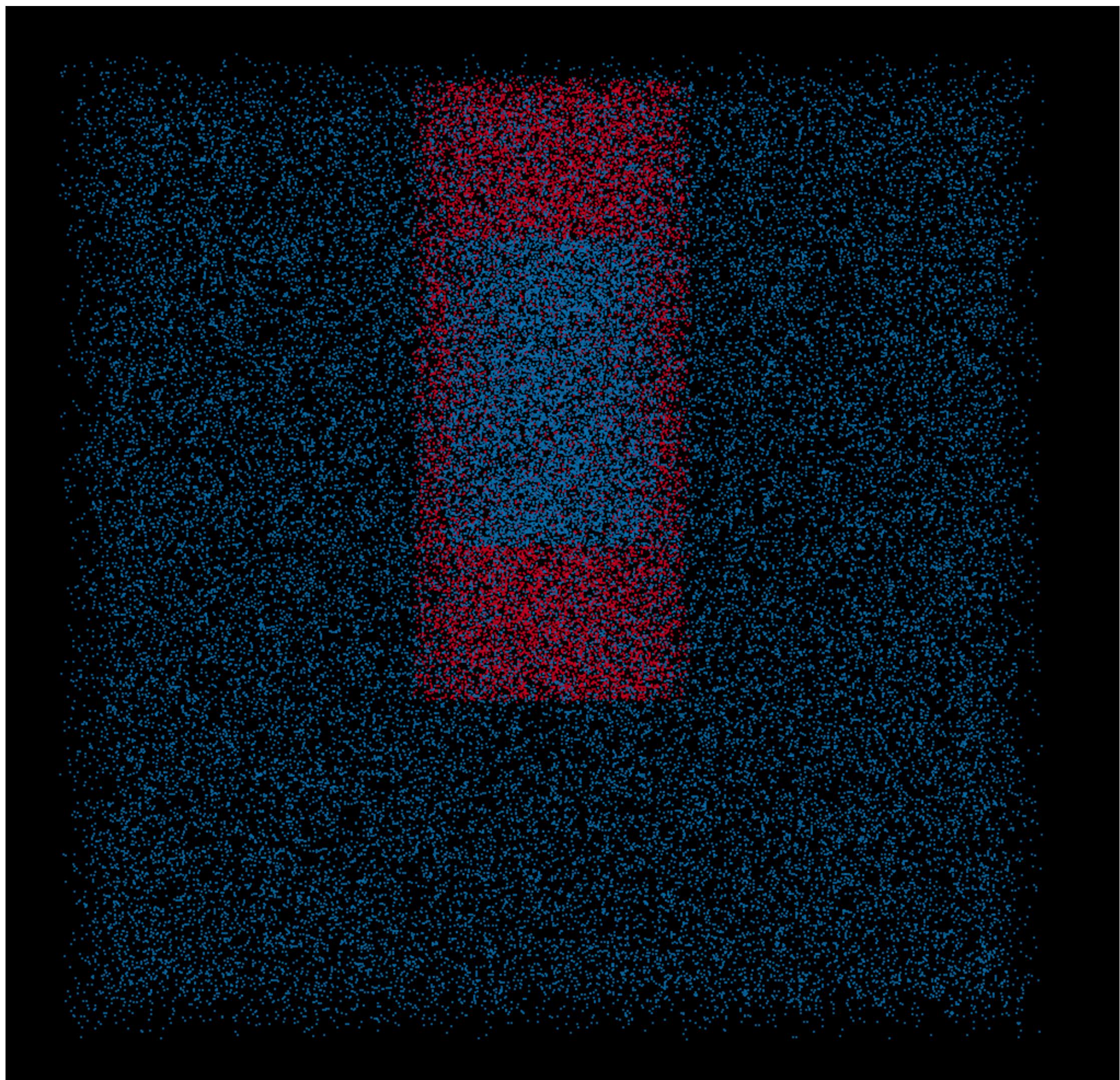
D1



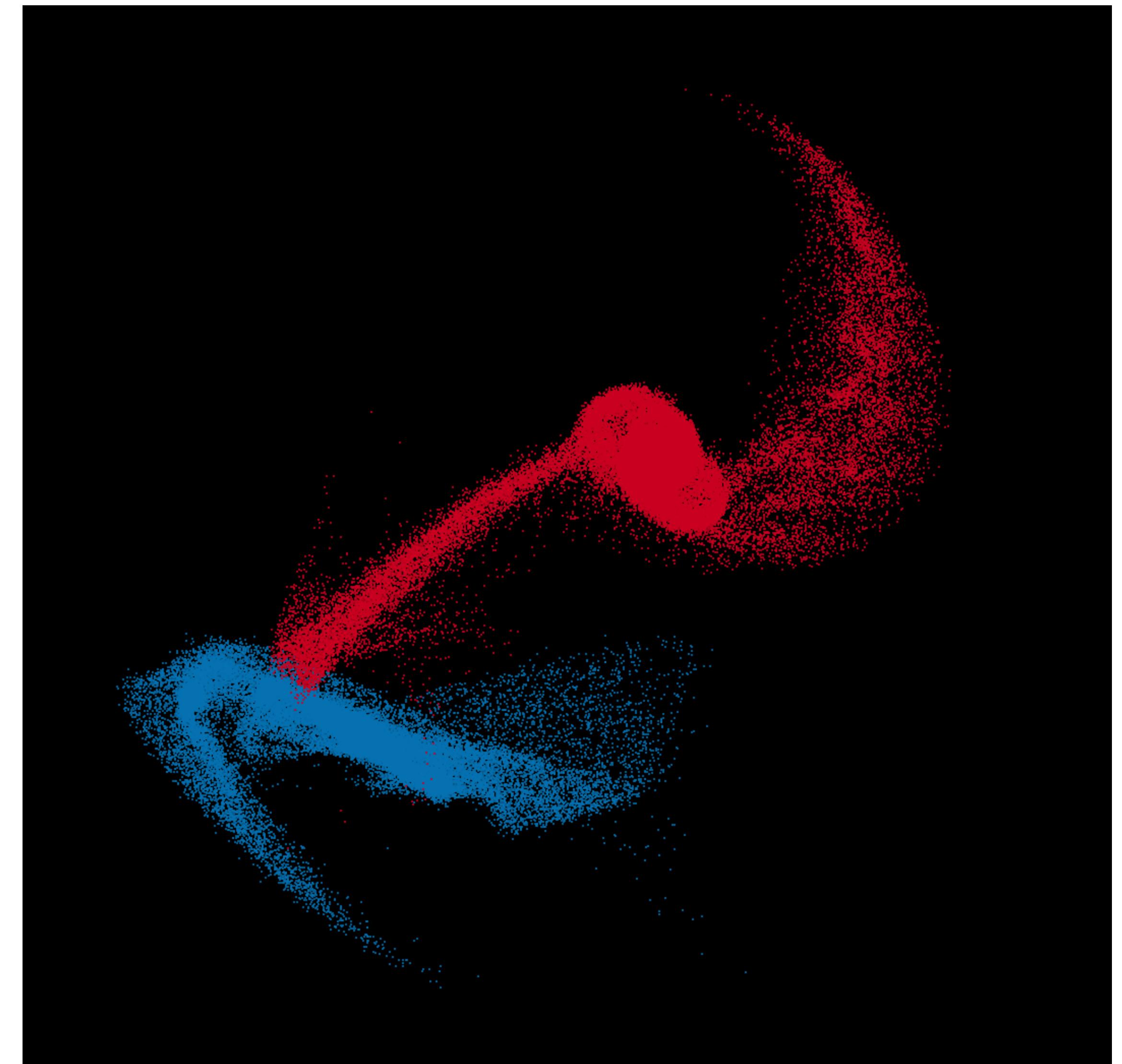
D2

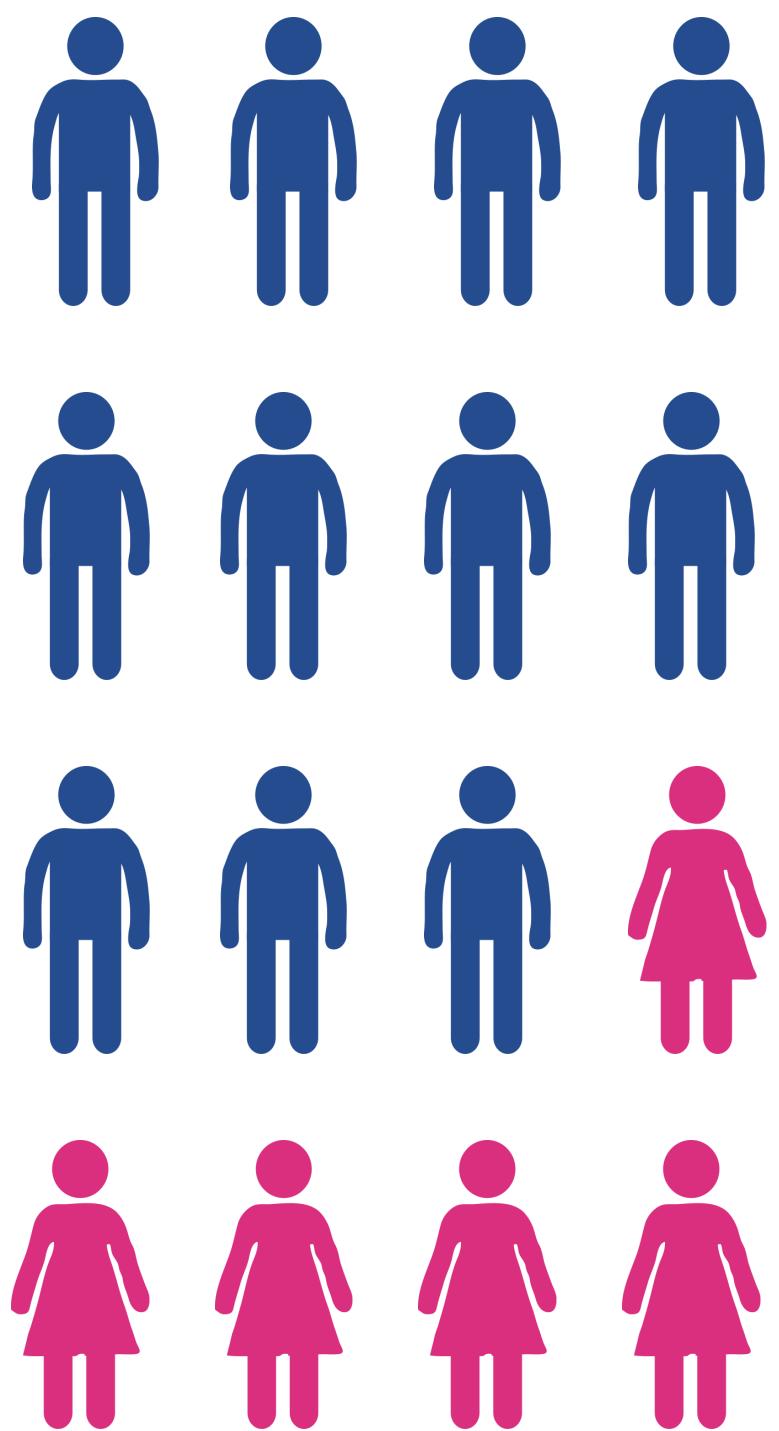


D3



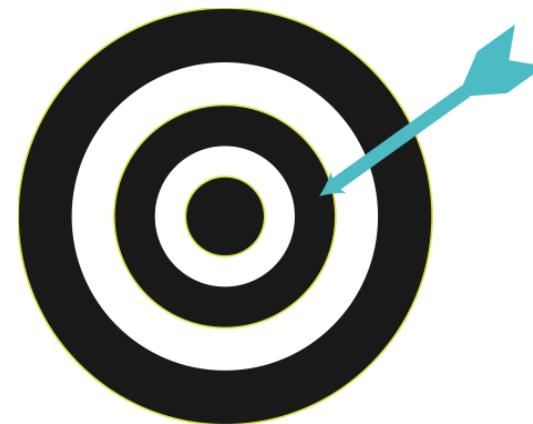
D4





 X 11

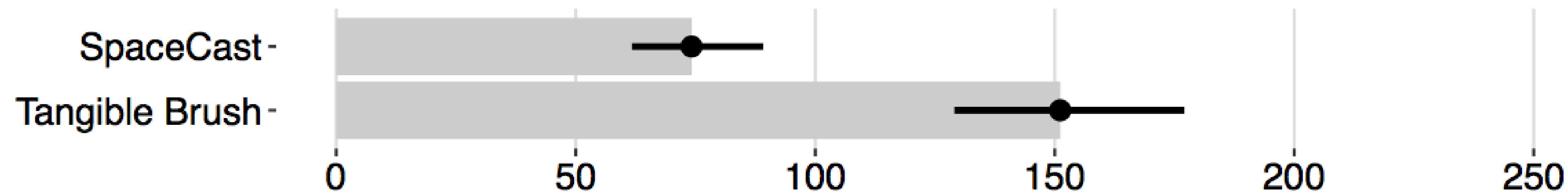
 X 5



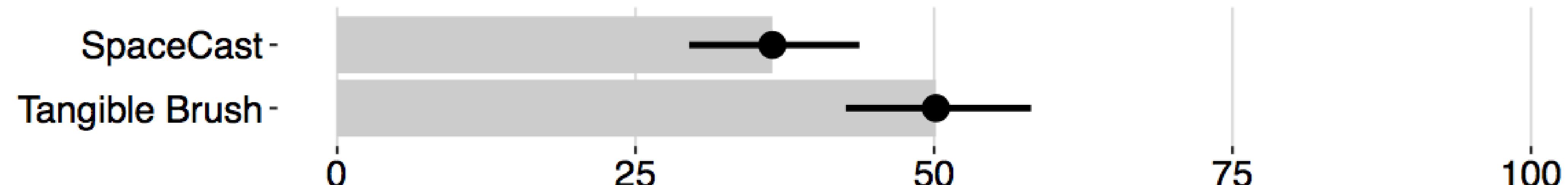
F1 score (higher is better). Error bars are 95%CIs



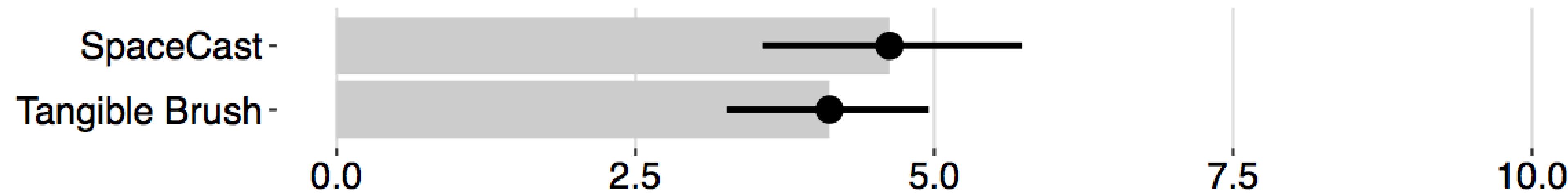
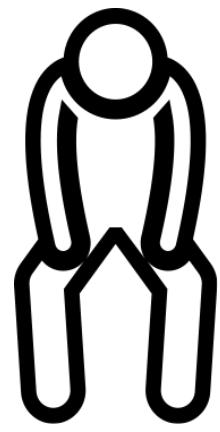
MCC score (higher is better). Error bars are 95%CIs



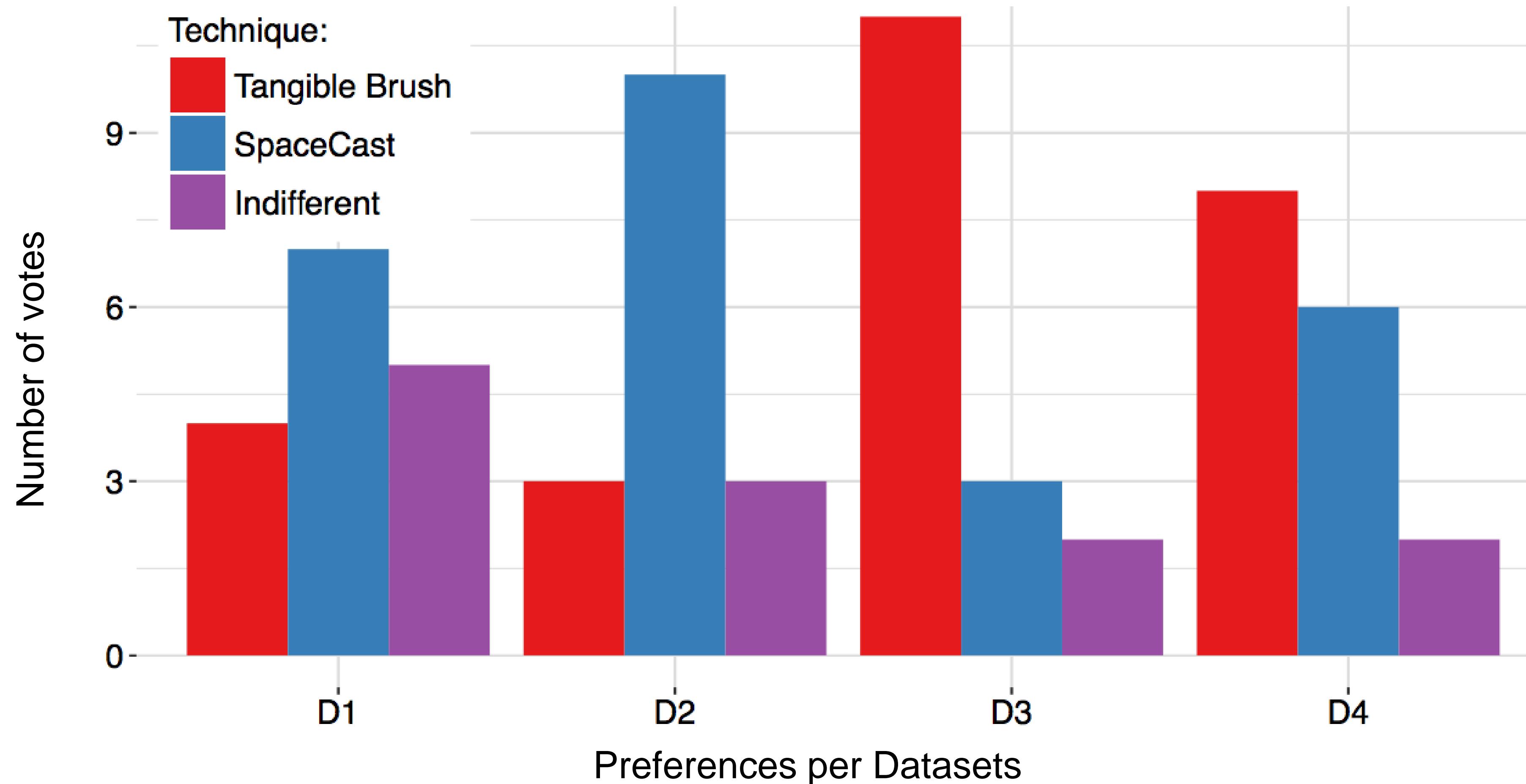
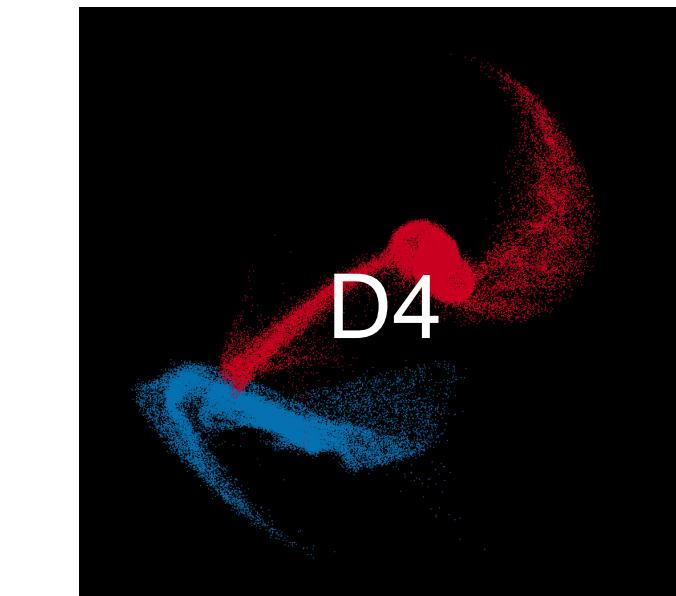
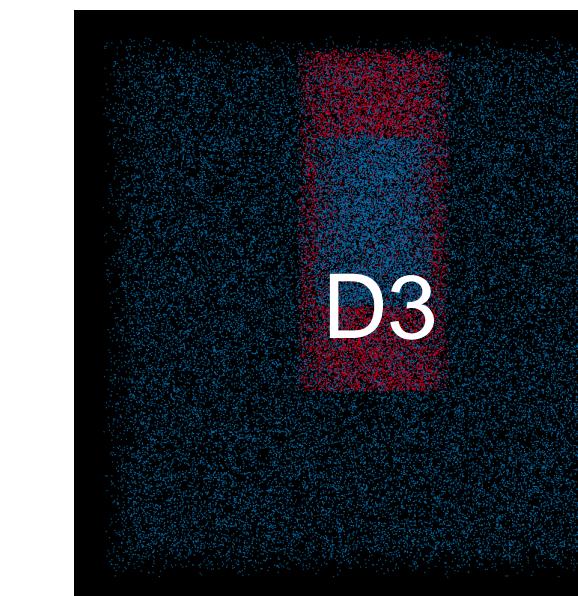
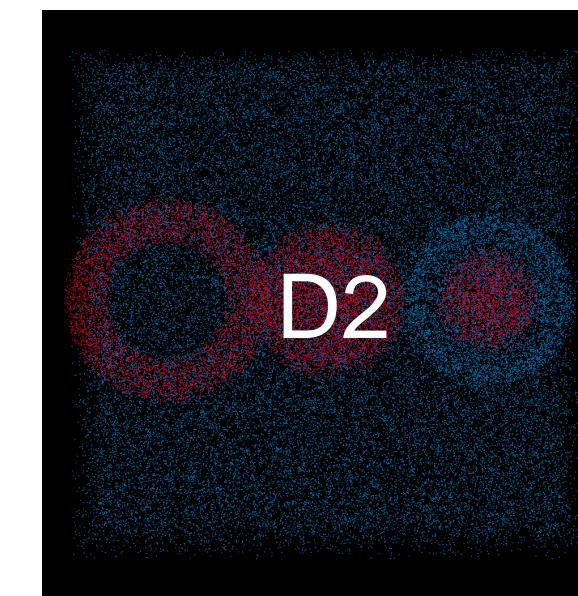
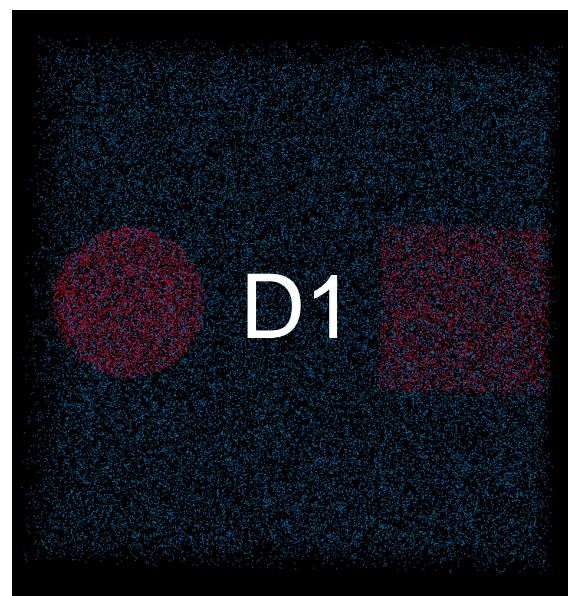
Completion Time in seconds. Error bars are 95%CIs

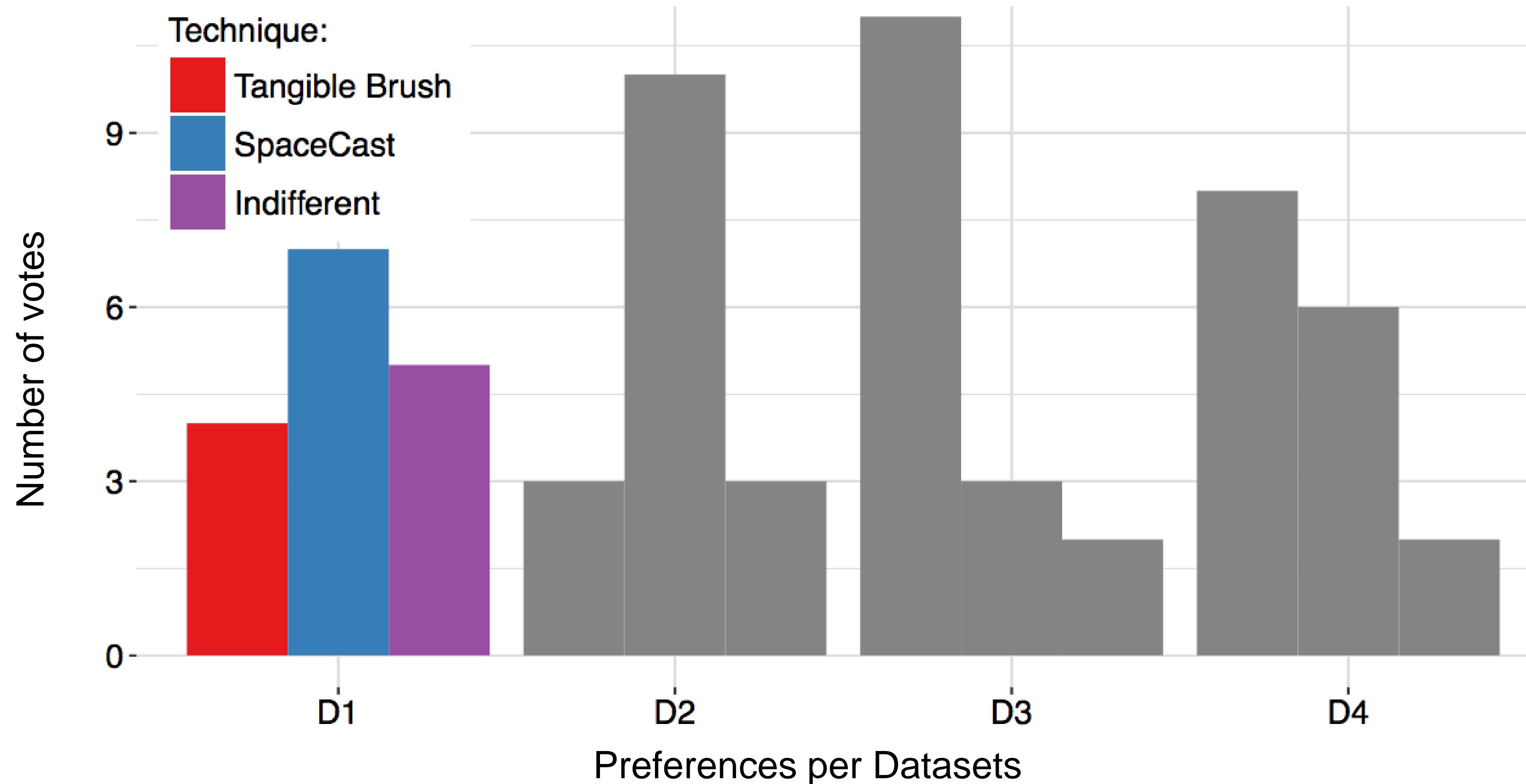
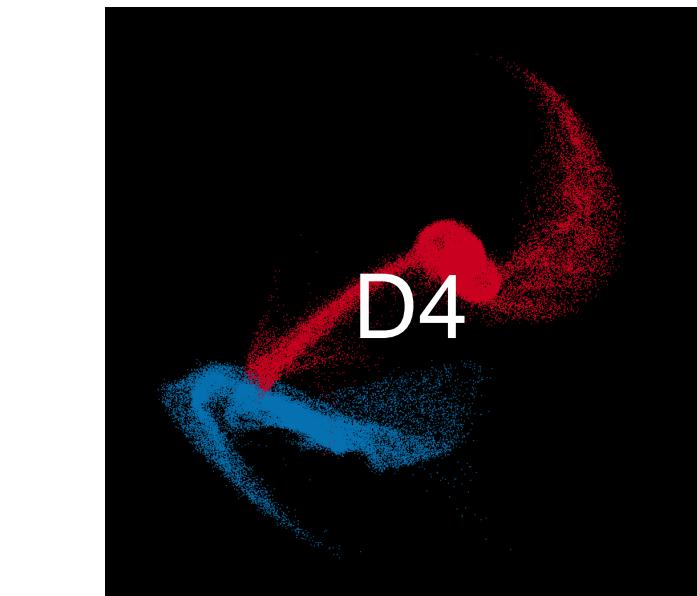
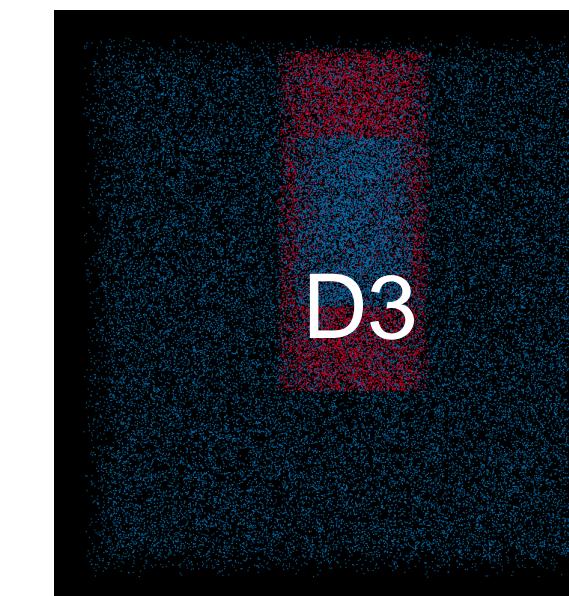
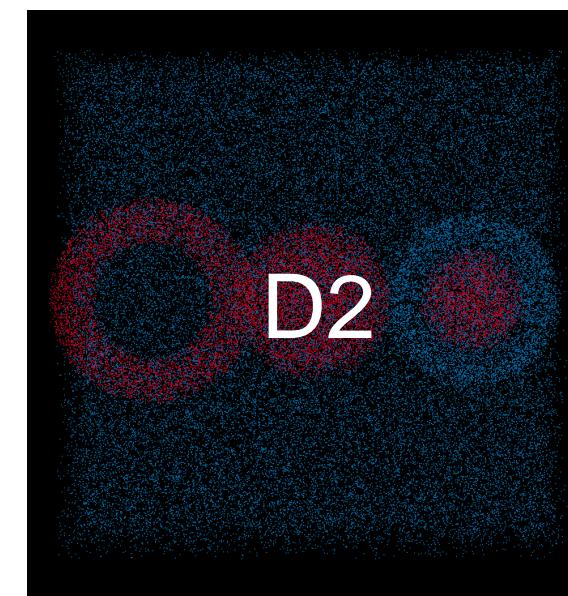
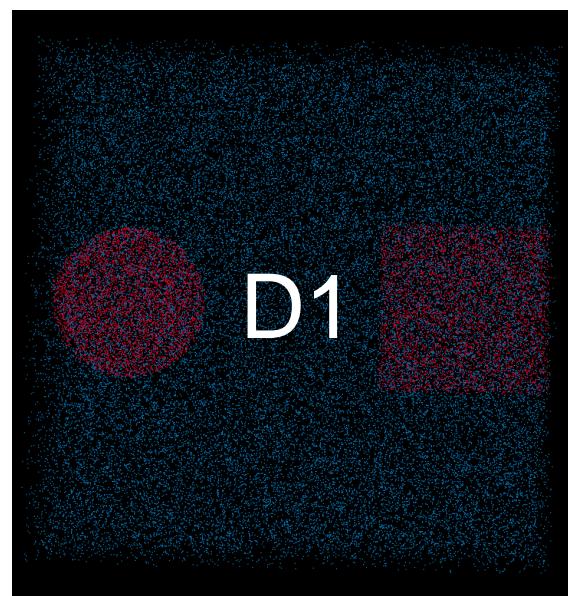


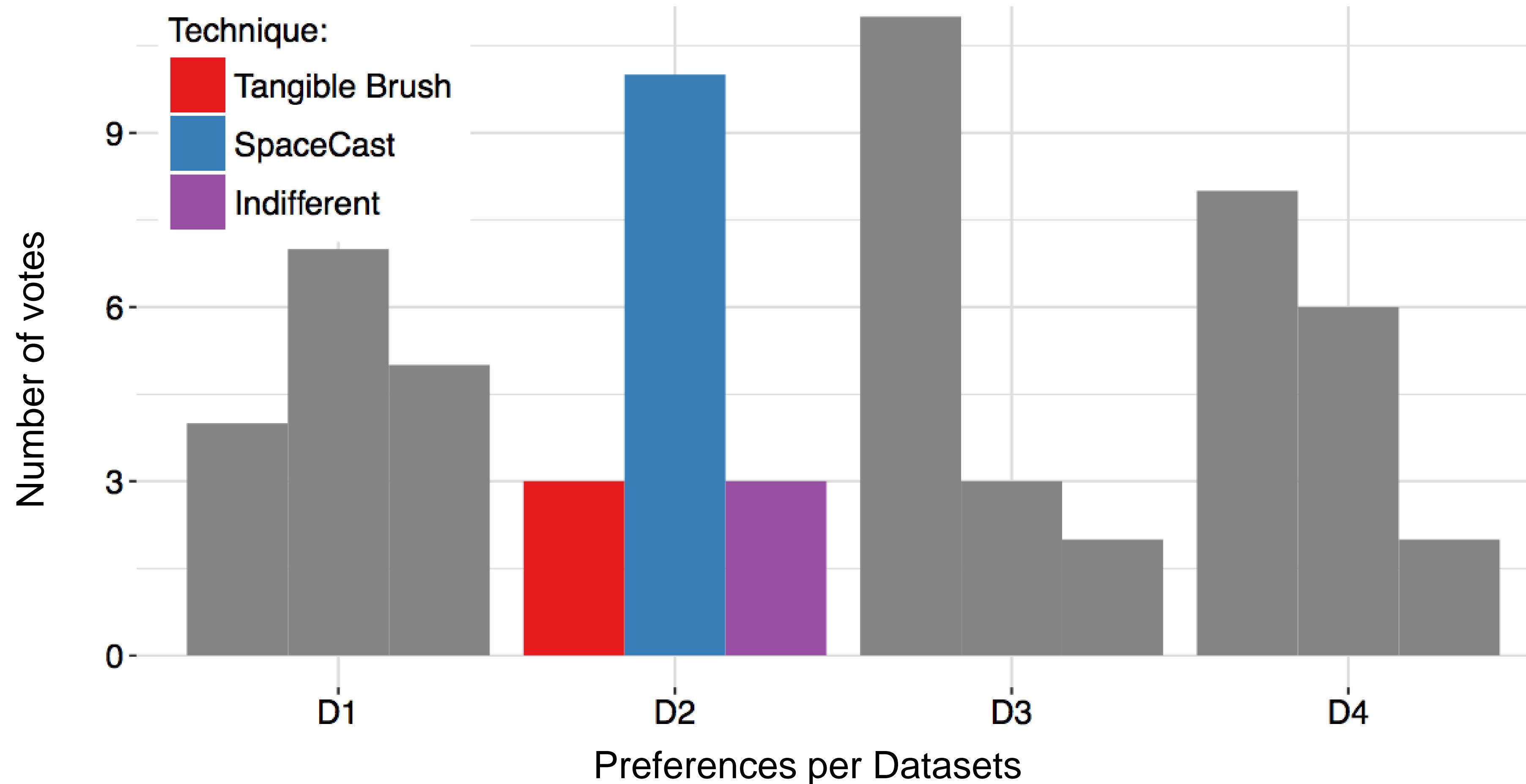
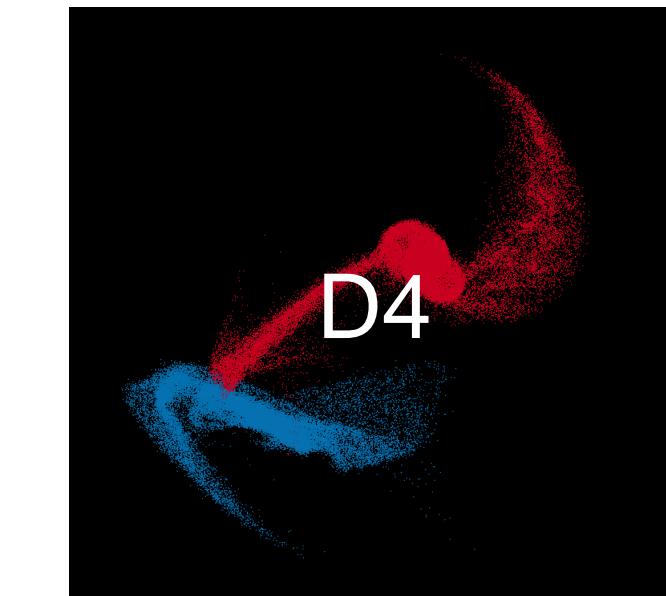
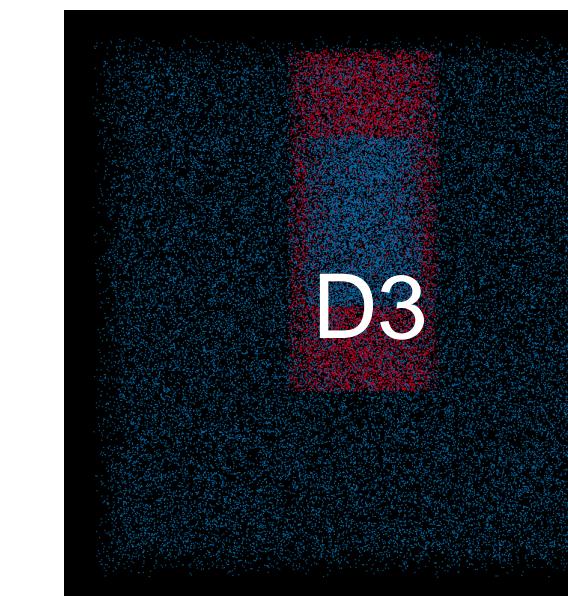
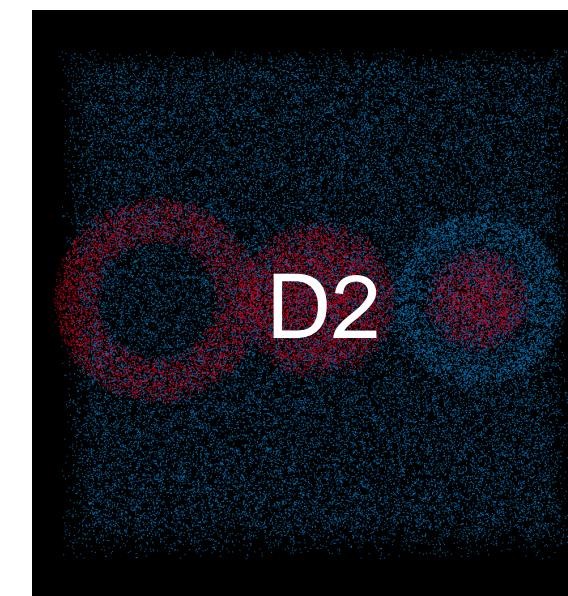
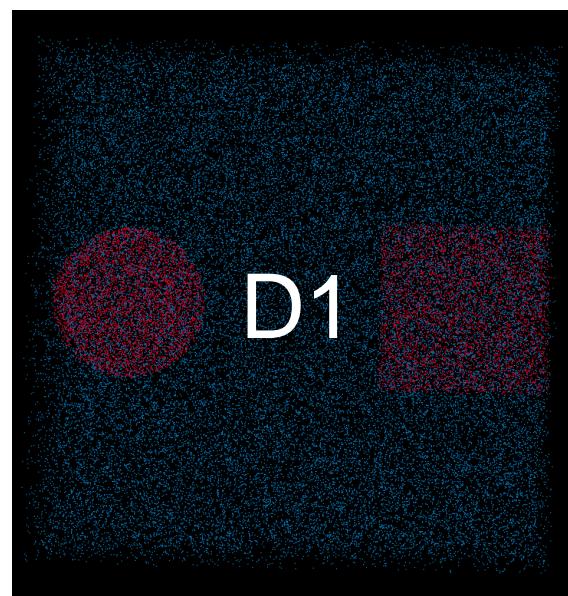
Total Workload. Error bars are 95% Bootstrap CIs

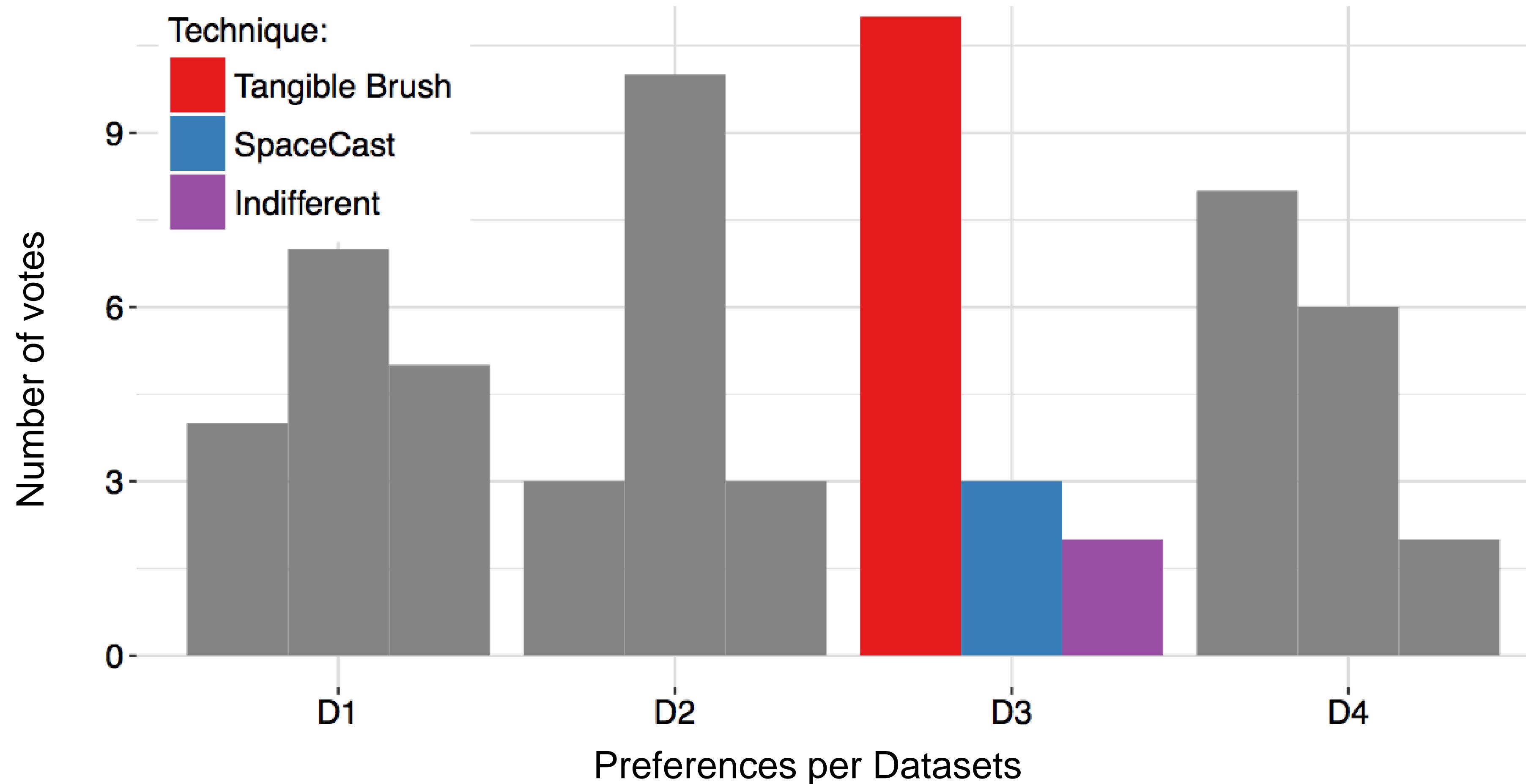
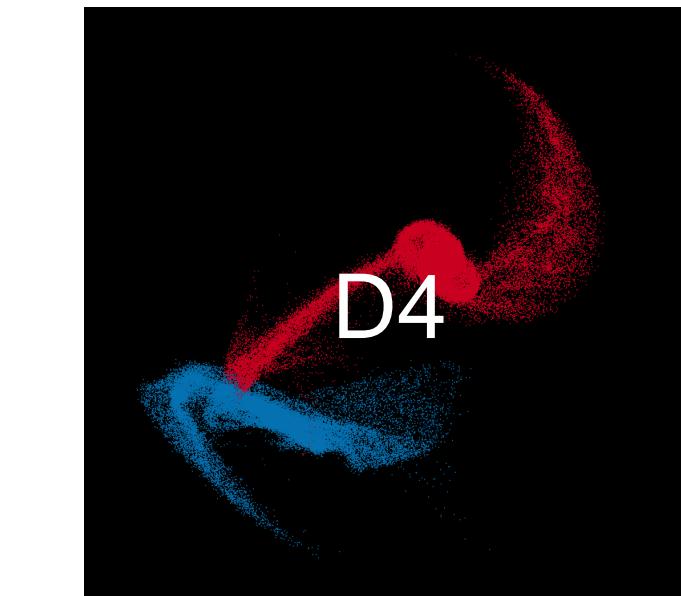
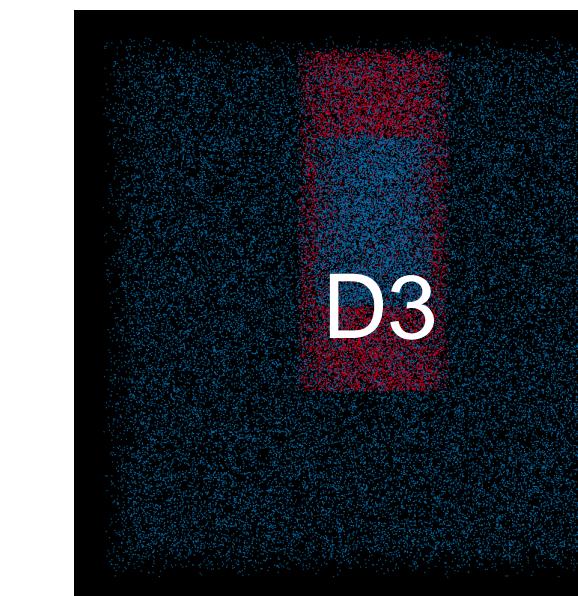
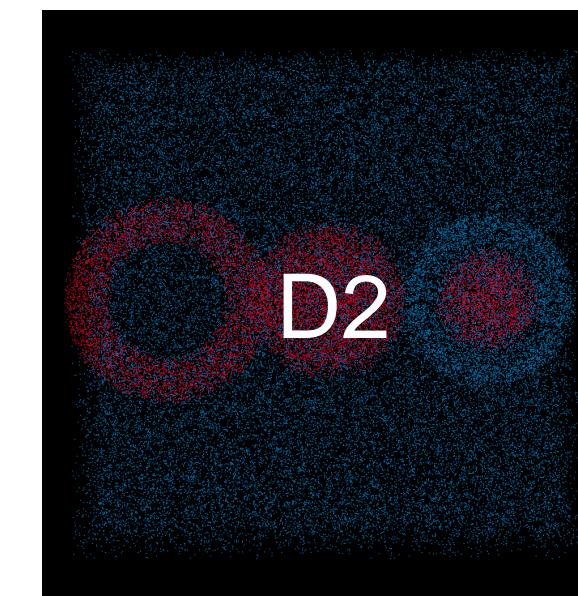
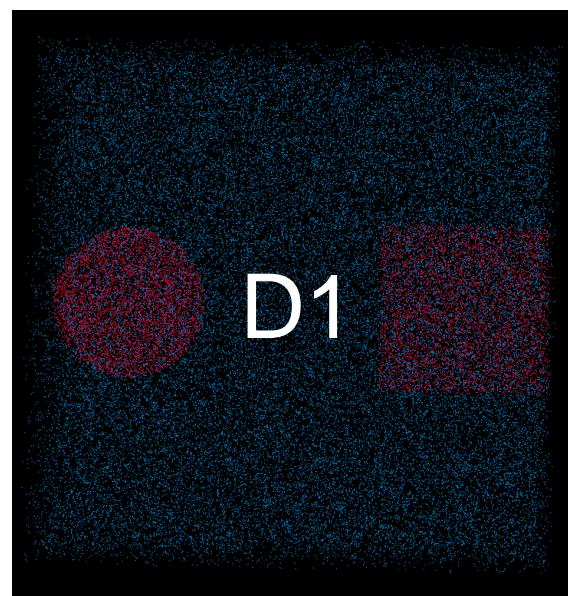


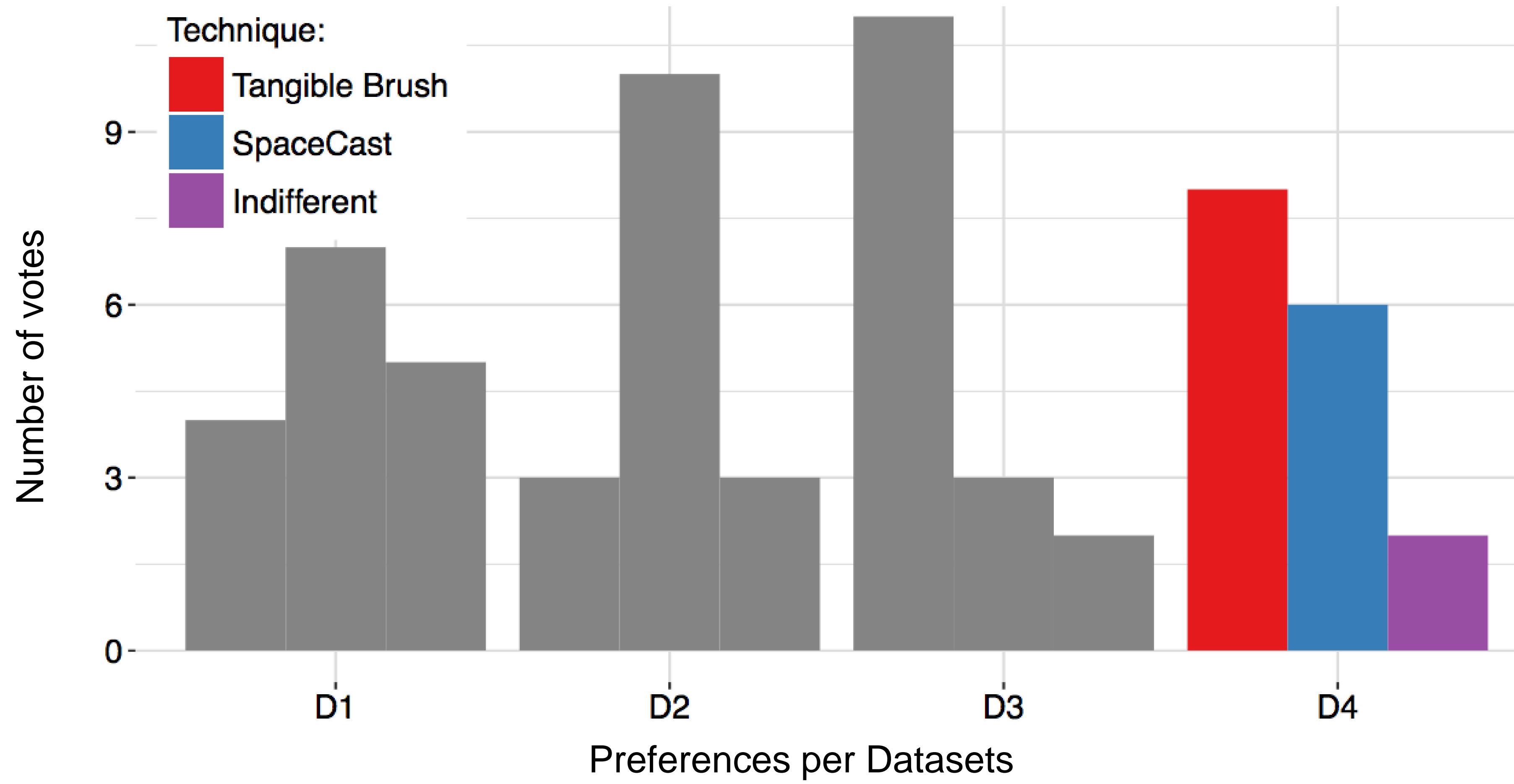
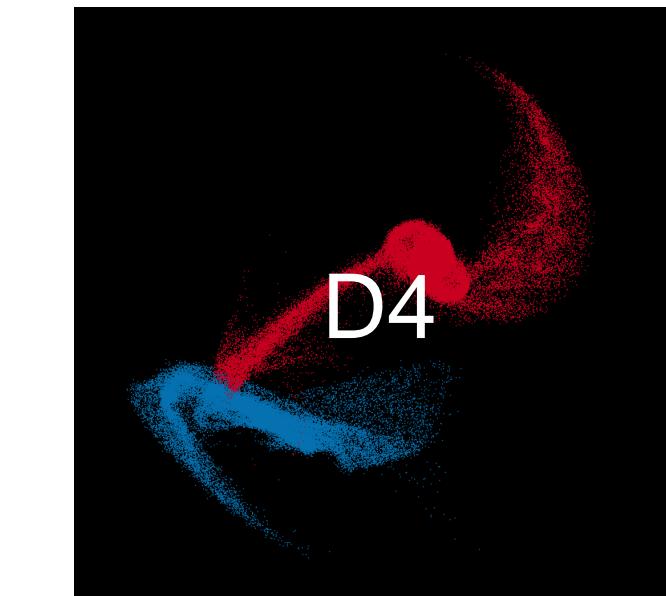
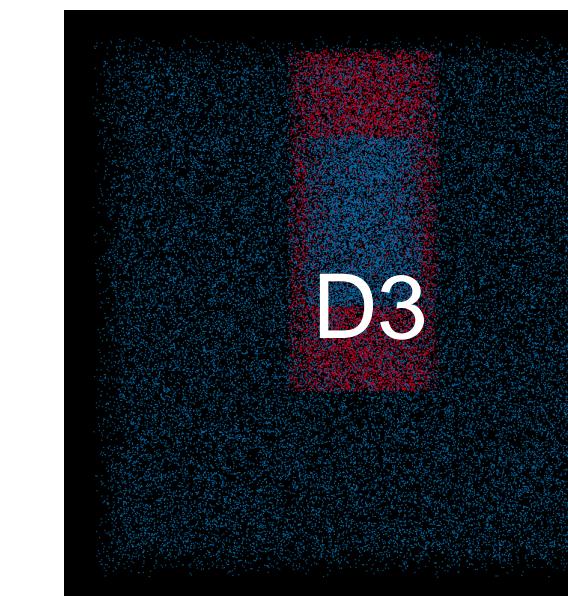
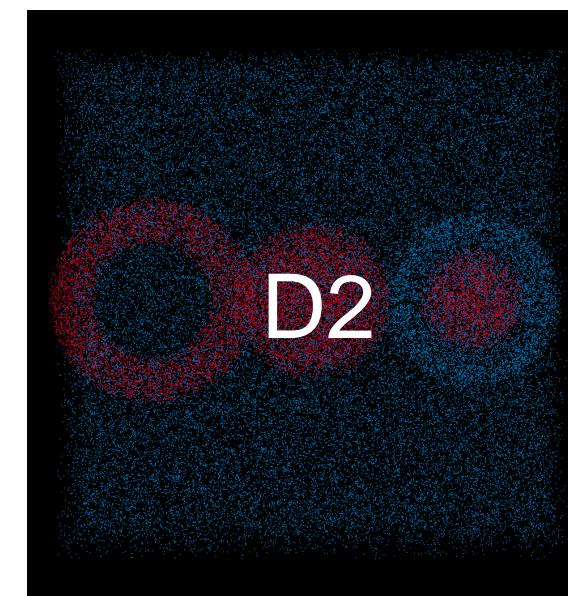
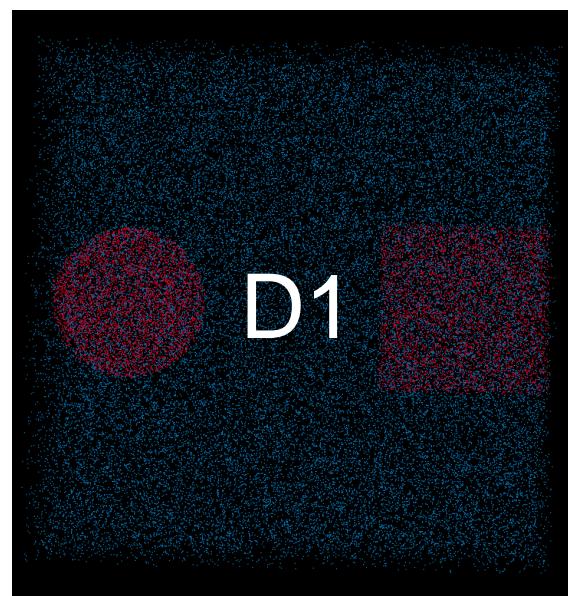
Total fatigue evaluation. Error bars are 95% Bootstrap CIs

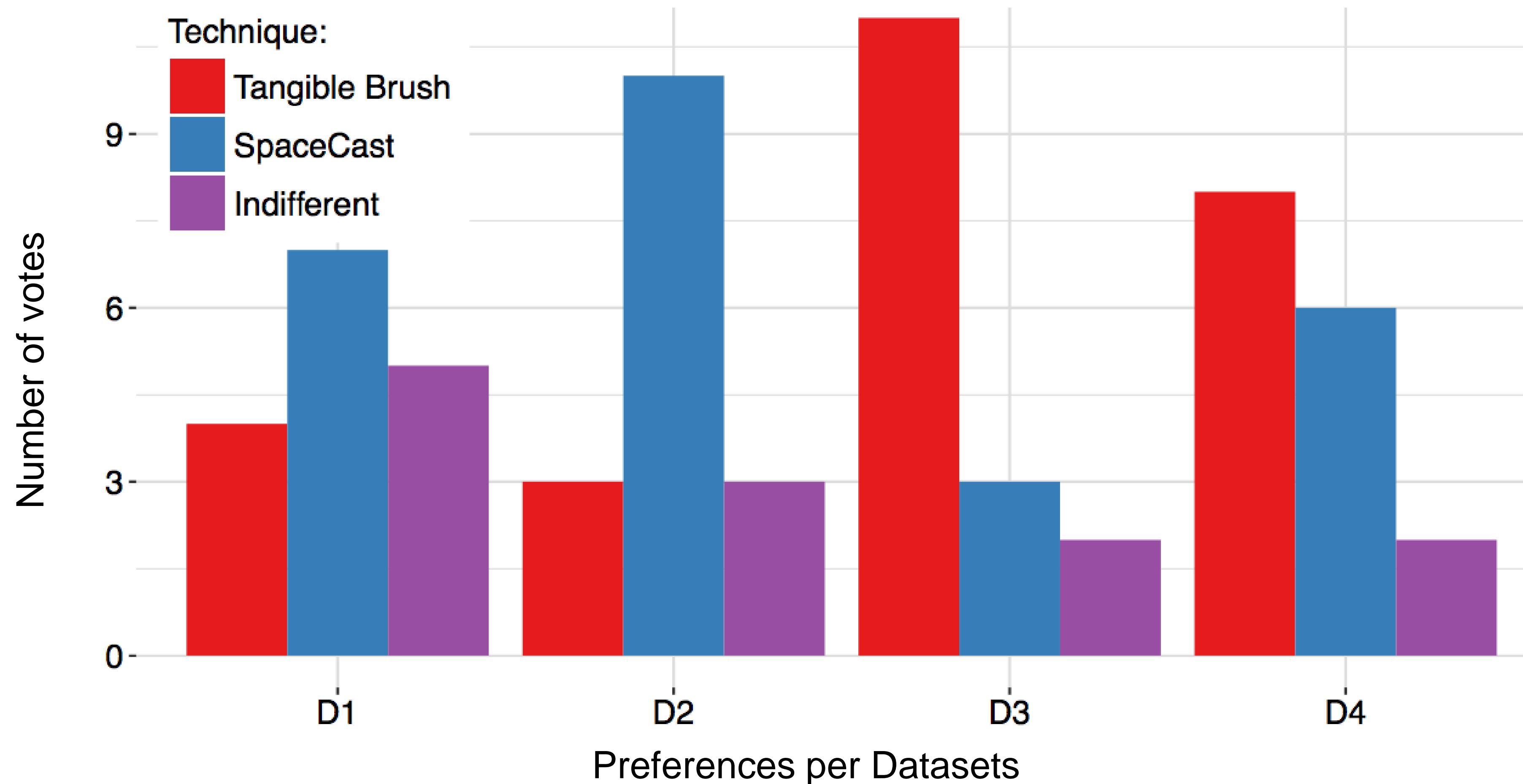
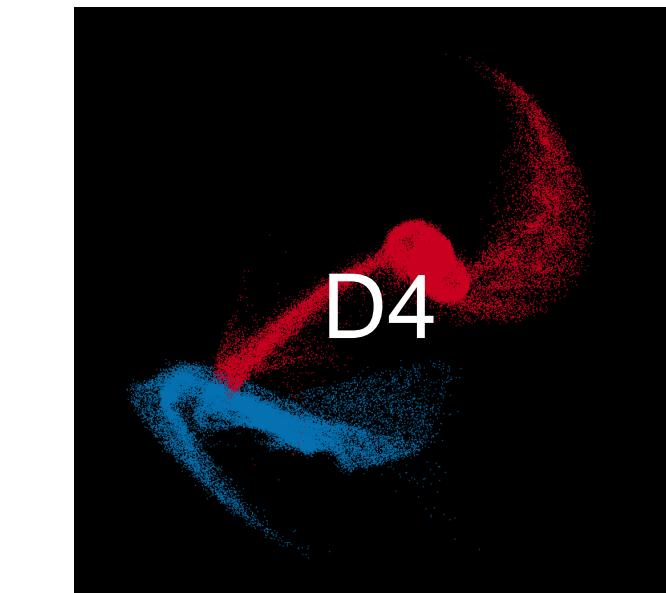
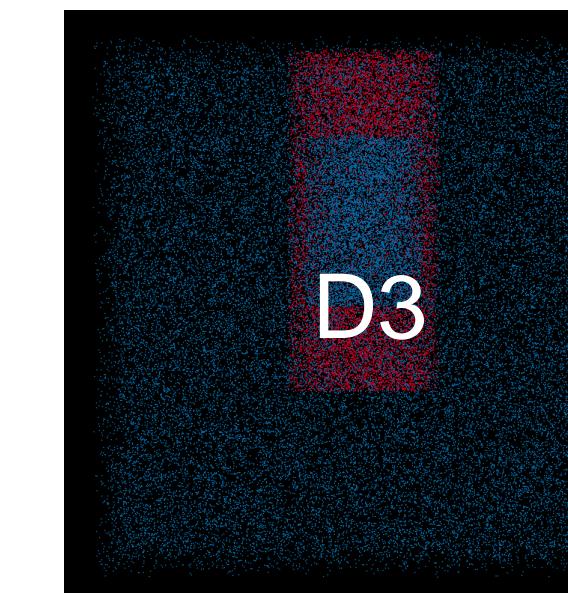
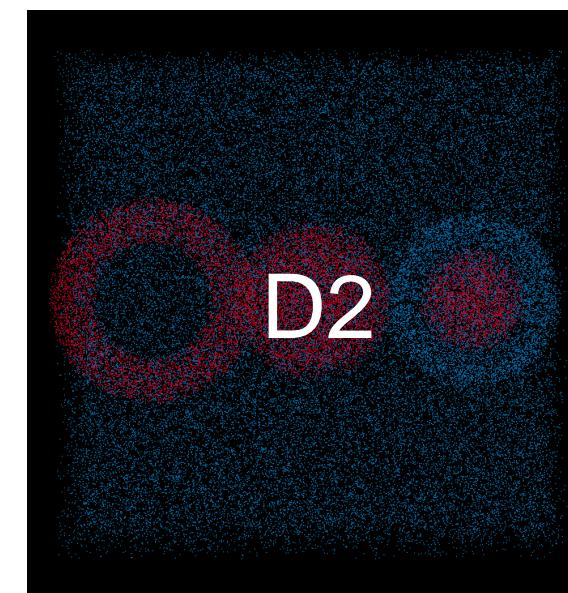
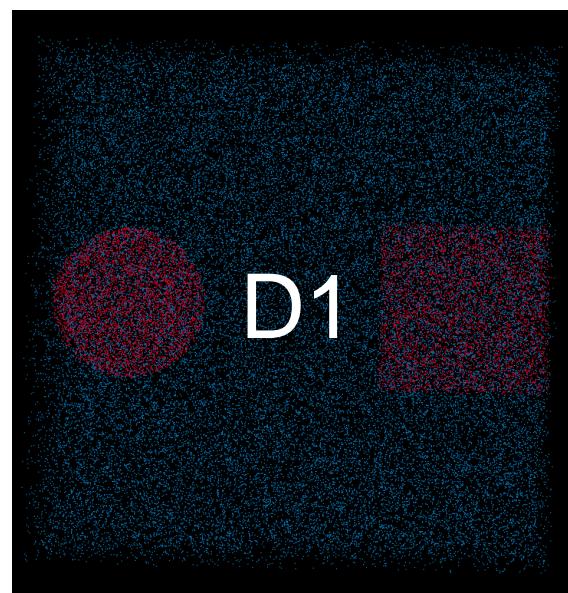




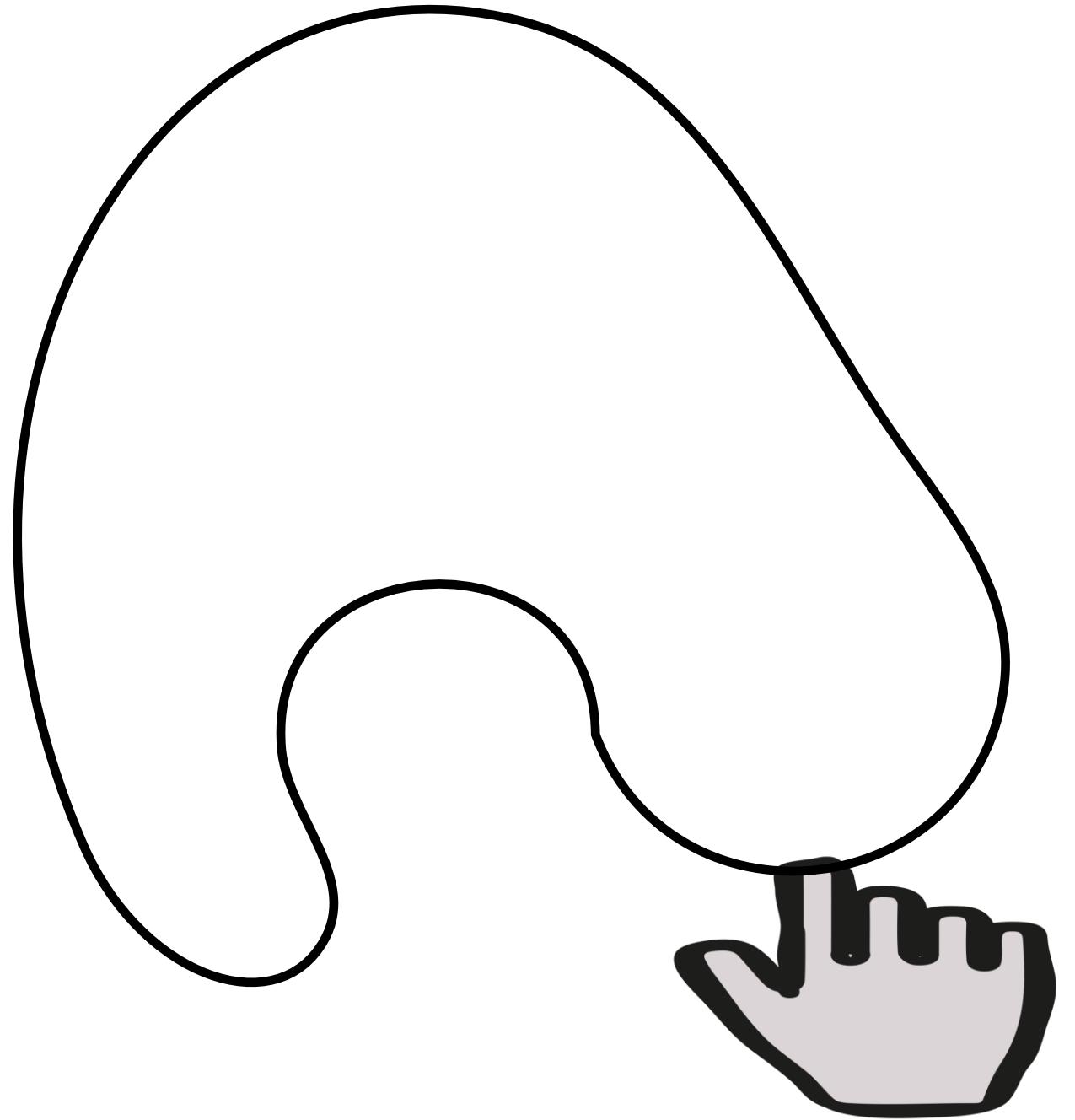




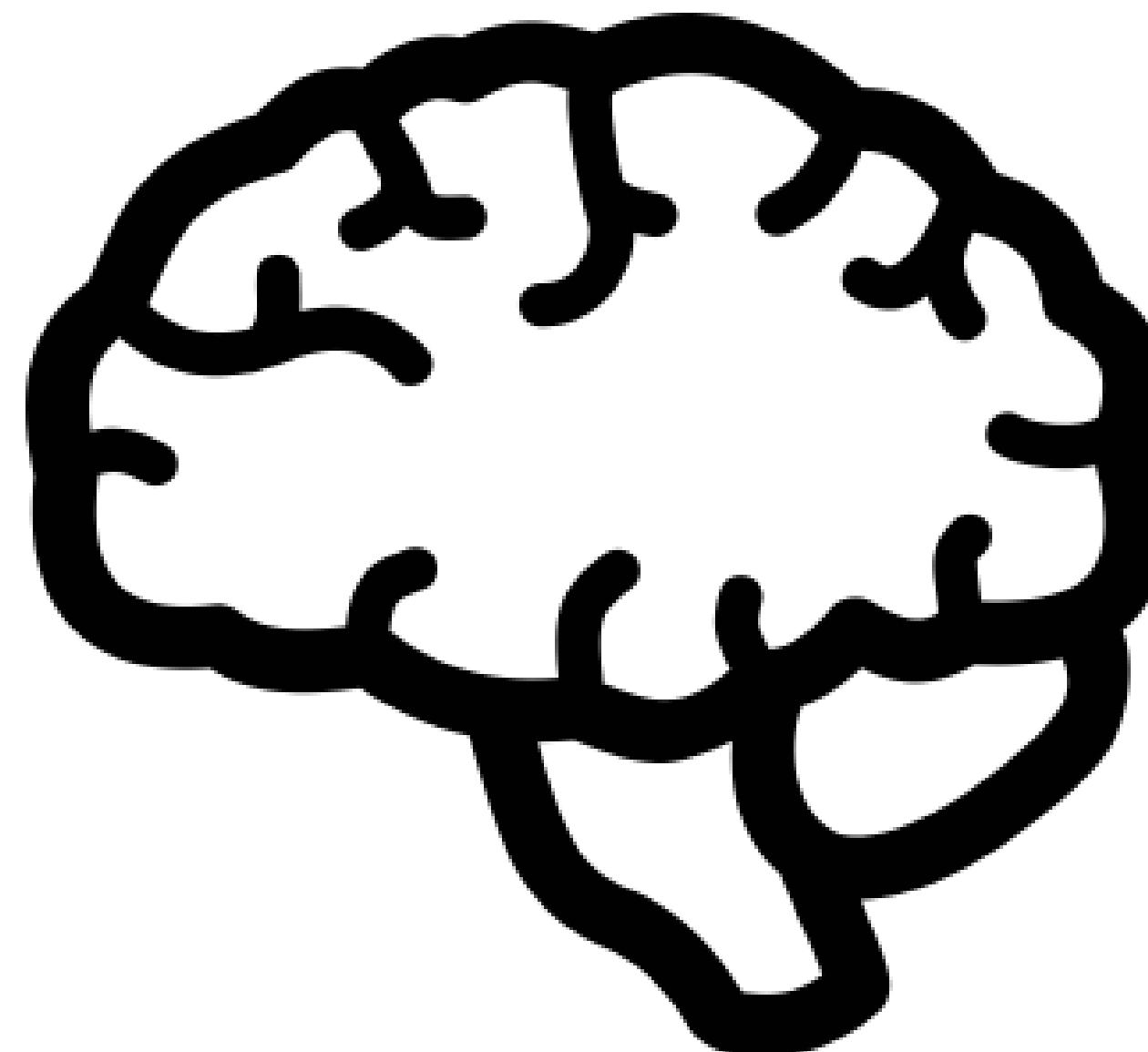
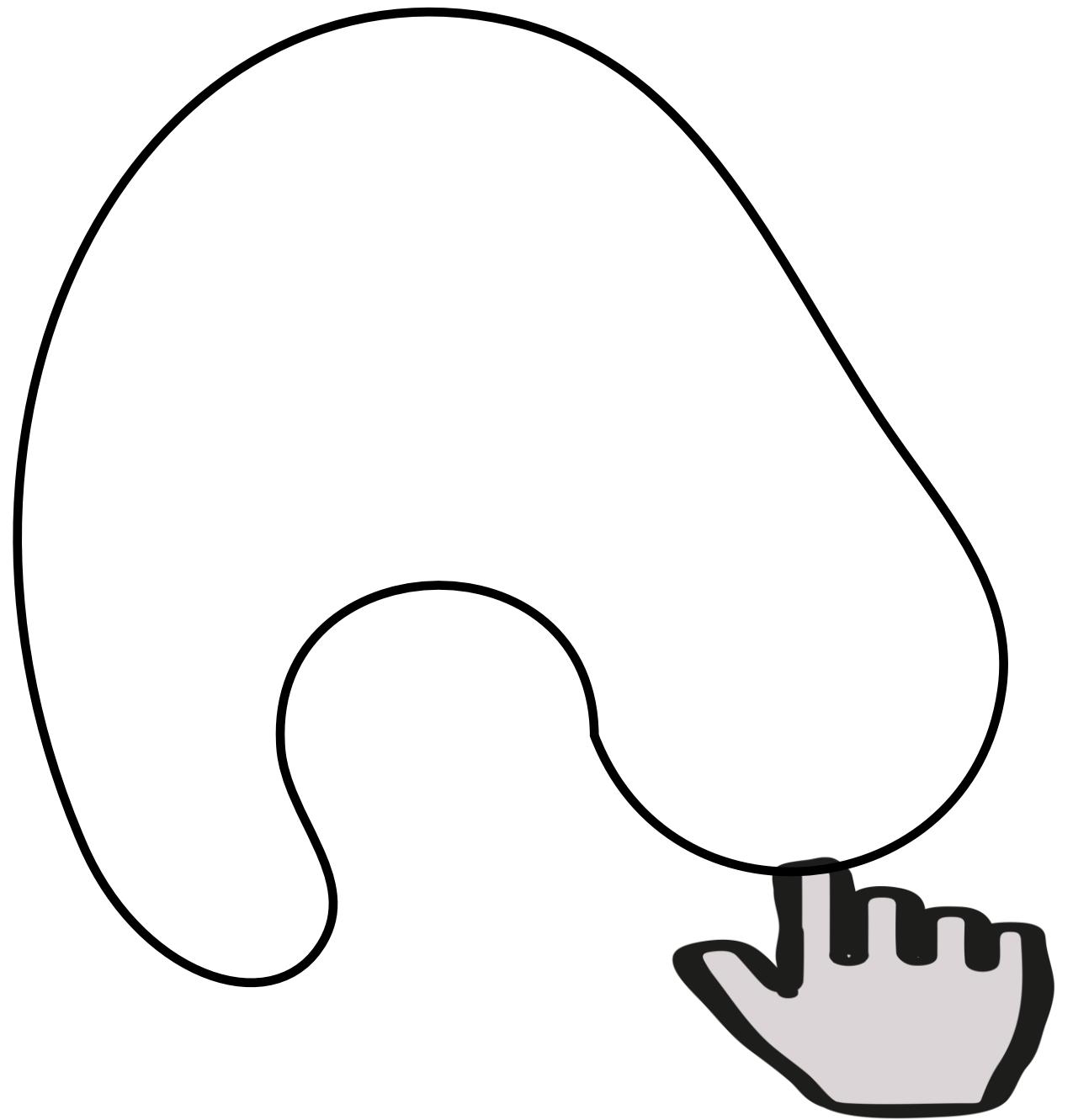




Limitations



Limitations



Limitations

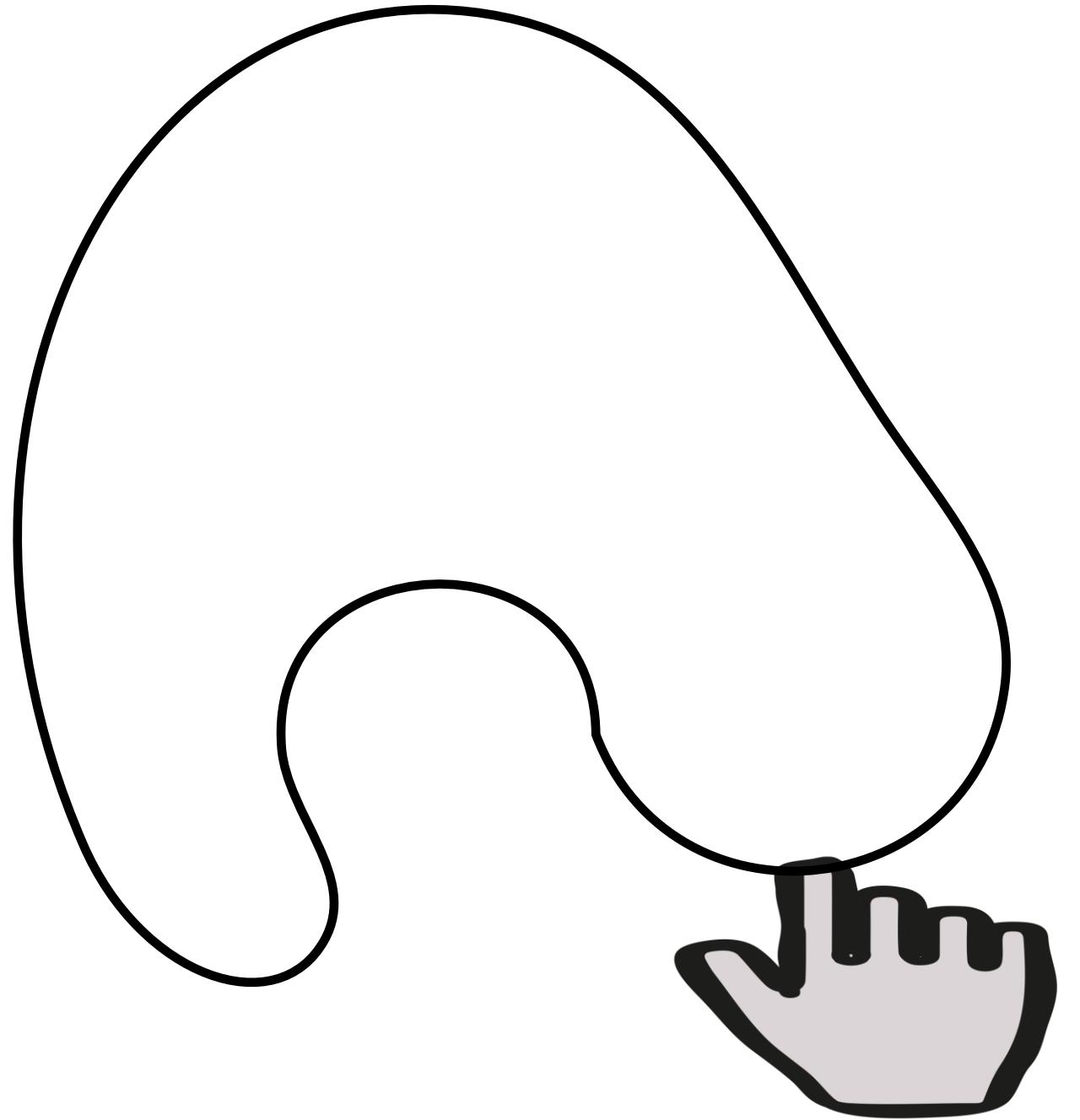
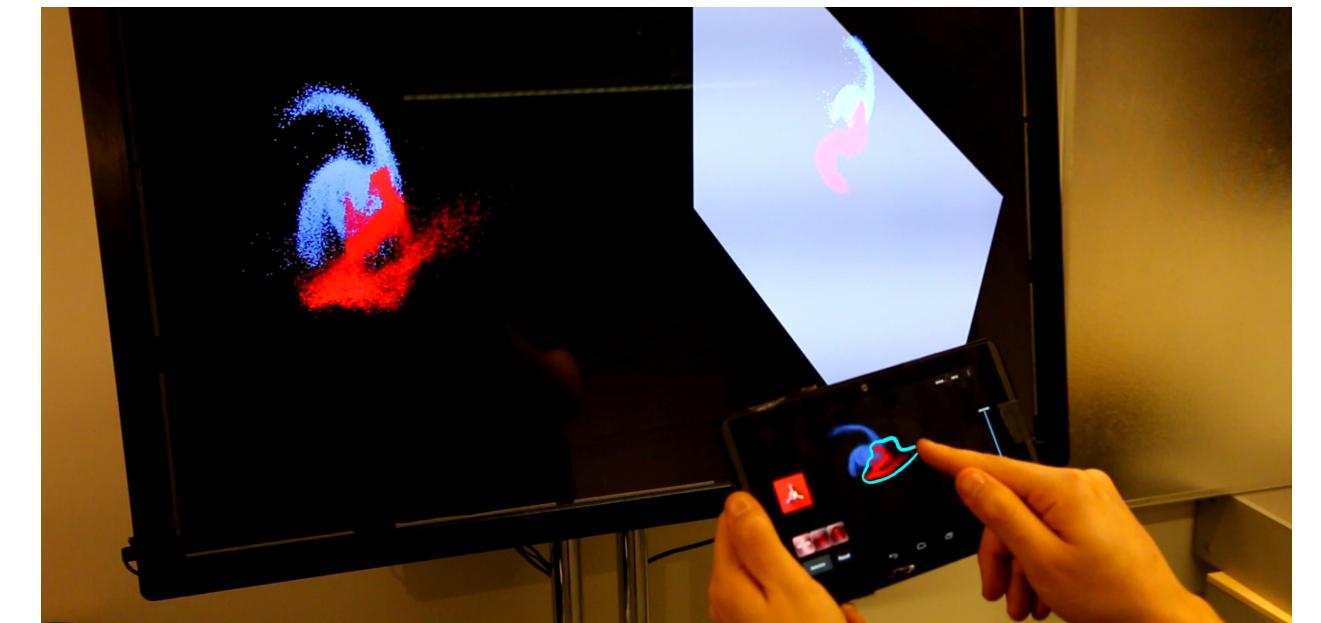


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Silk Cursor [ZBM94]	box	object	no control	no control	3 DOF	6 DOF	none
Bubble Cursor [VGC07]	sphere	object	no control	automated adjust.	6 DOF	6 DOF	none
Aperture [FHZ96]	cone	object	no control	manual size adjust.	5 DOF (trans.: 2, rot.: 3)	6 DOF	none
SQUAD [KBB11]	sphere + ray	object	no control	automated adjust.	5 DOF	6 DOF	none
Senseshapes [OBF03]	cone/sphere/box	object	no control	no control	5 DOF	6 DOF	none
Cylinder Selection [LBCW05a]	lasso	ROI	semi-autom., 2D input	no control	2 DOF	2 DOF	none
CloudLasso [YEI12]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
CAST [YEI16]	lasso	ROI	semi-autom., 2D input	threshold adjust.	2 DOF	2 DOF	none
Tangible Brush	lasso + extrusion	ROI / objects	manual	none	up to 6 DOF	up to 6 DOF	manual

An extended taxonomy that takes into account the control users have over the shape of the selection volume.

Tangible Brush: a versatile selection technique that gives users a lot of control over the shape of their selection.



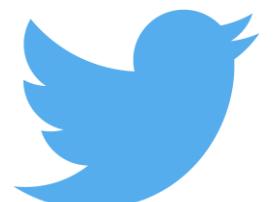
A user study that showed that Tangible Brush can be very precise with a cost on completion time.



Hybrid touch/tangible Spatial 3D data selection



Lonni Besançon, Mickael Sereno, Linyun Yu, Mehdi Ammi, Tobias Isenberg



@lonnibesancon



lotti.besancon@gmail.com