Implementing virtual partners for sensorimotor synchronization research

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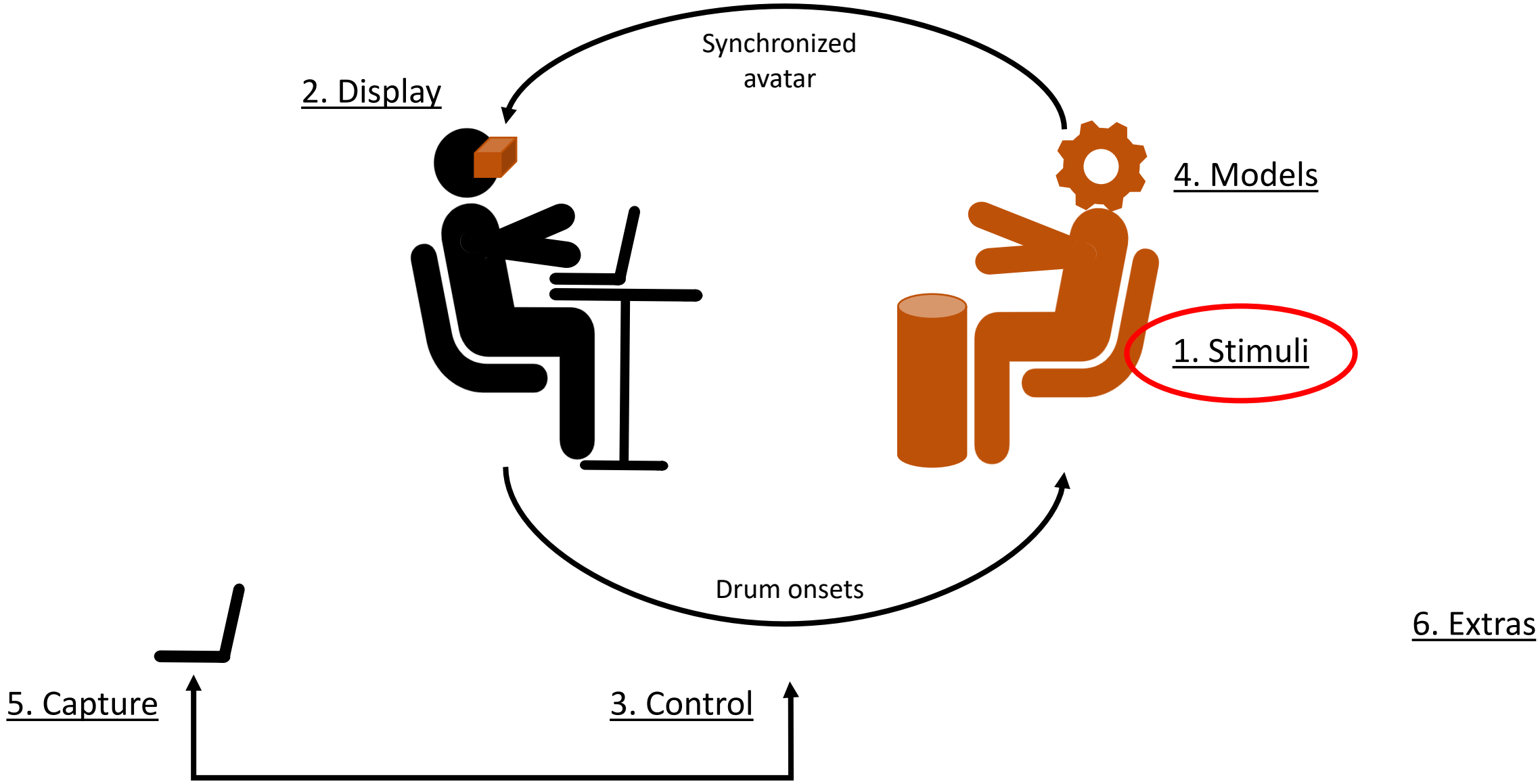
Interpersonal coordination

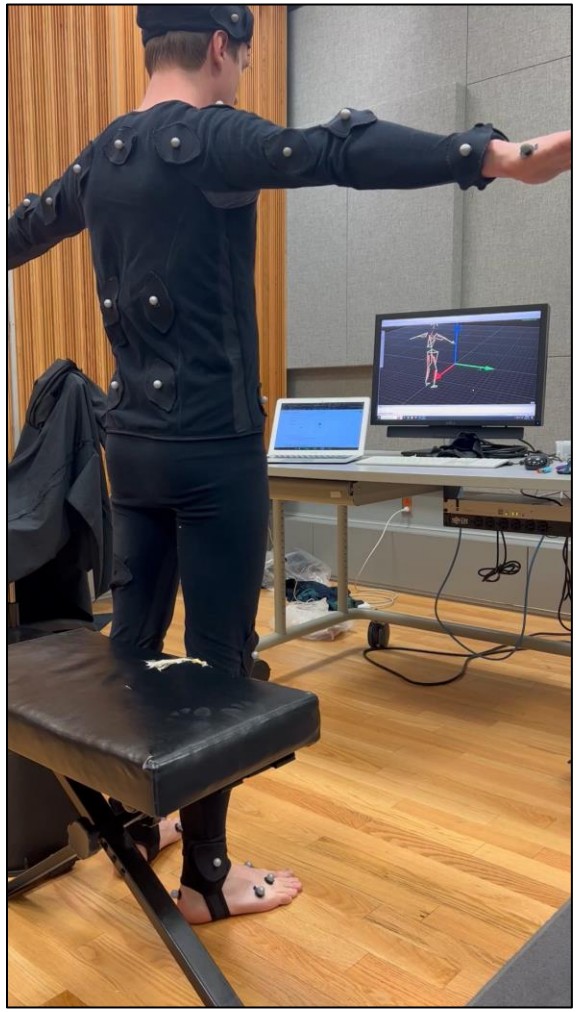
Computational modelling

Virtual partner interaction paradigms

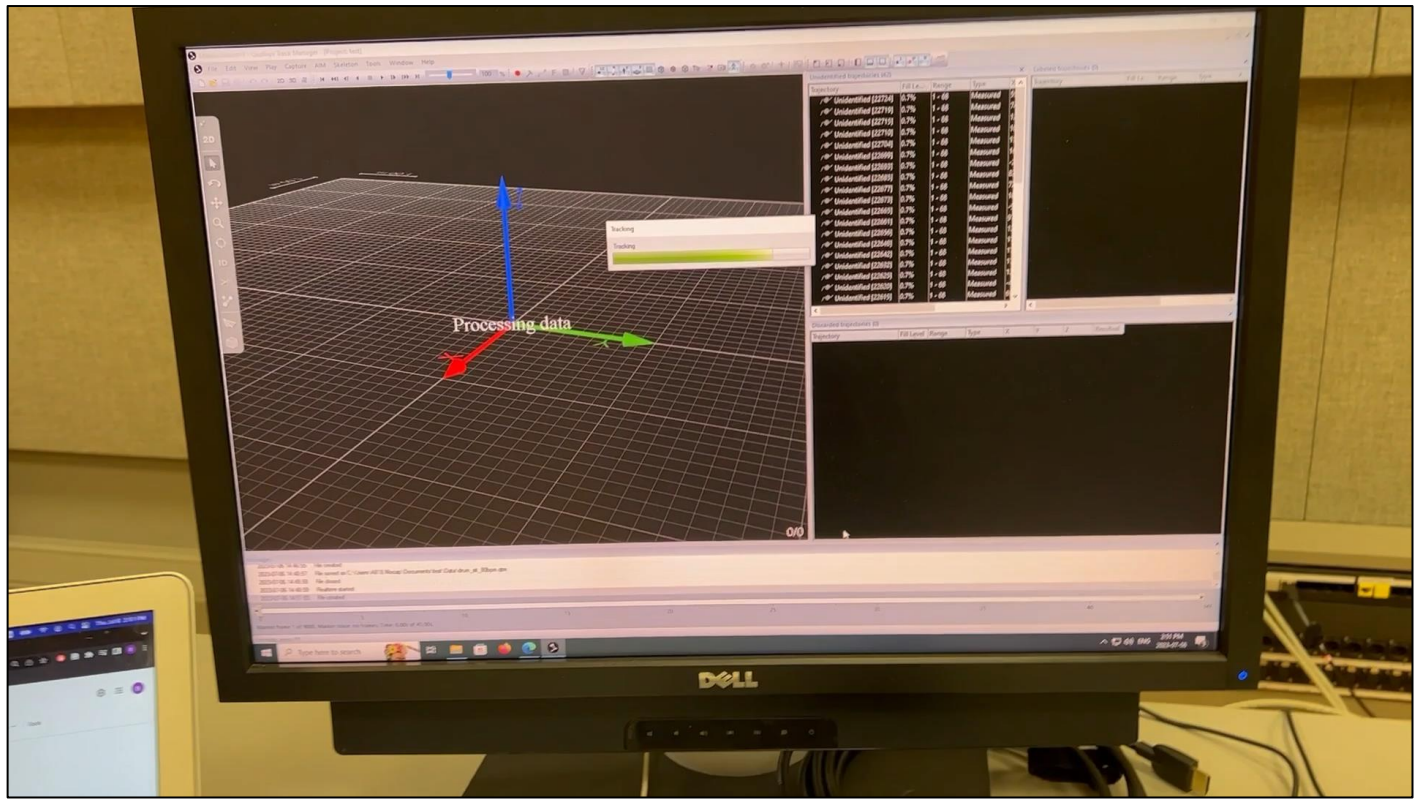
XR and embodied interaction

[Demos, AP, Palmer, C. "Social and nonlinear dynamics unite: Musical group synchrony." Trends in Cognitive Sciences (2023)]
[Kelso, JA Scott, et al. "Virtual partner interaction (VPI): exploring novel behaviors via coordination dynamics." PloS one (2009)]
[Van Kerrebroeck, B, et al. "A methodological framework for assessing social presence in music interactions in virtual reality." Frontiers in Psychology (2021)]


Synchronized
avatar
2. Display
4. Models
1. Stimuli
Drum onsets
6. Extras
5. Capture
3. Control




Qualisys Track Manager
2020
QUALISYS


Processing data
DELL

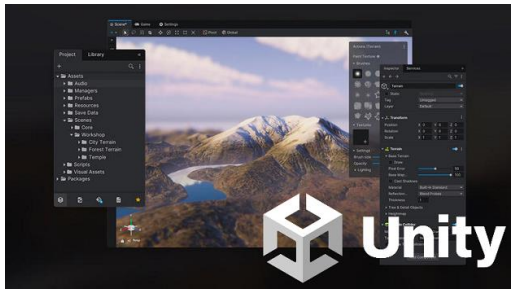
Avatars, agents, and animations

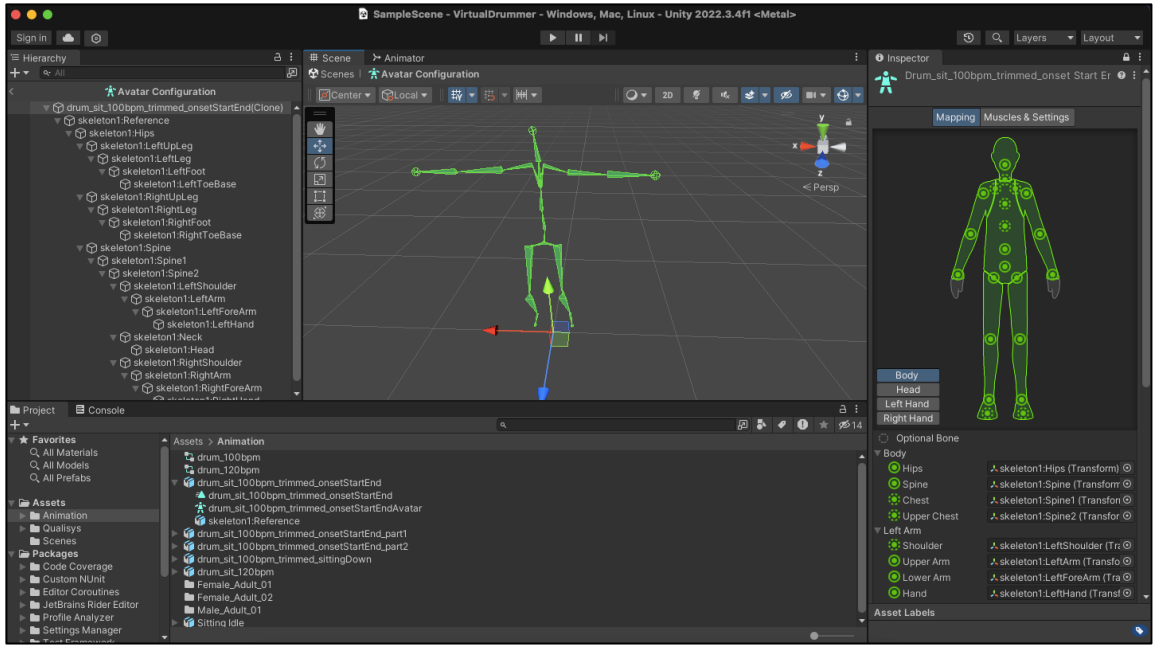
- Humanoids
- Skinning and rigging
- State-flow diagrams
- Inverse kinematics

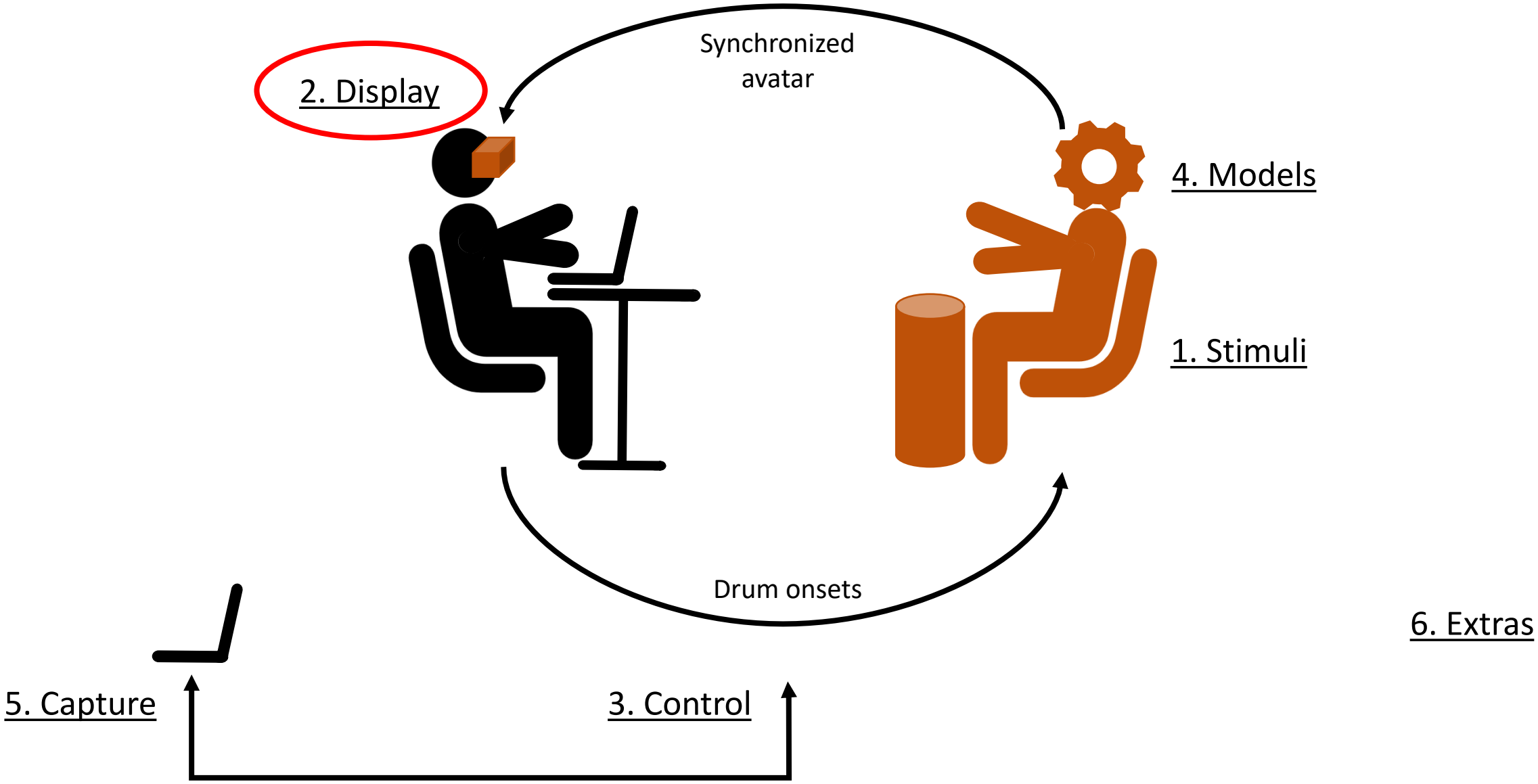
Animation and avatar databases

- www.github.com/microsoft/Microsoft-Rocketbox
- www.mixamo.com

Combining animations






2. Display
Synchronized avatar
4. Models
1. Stimuli
Drum onsets
6. Extras
5. Capture
3. Control

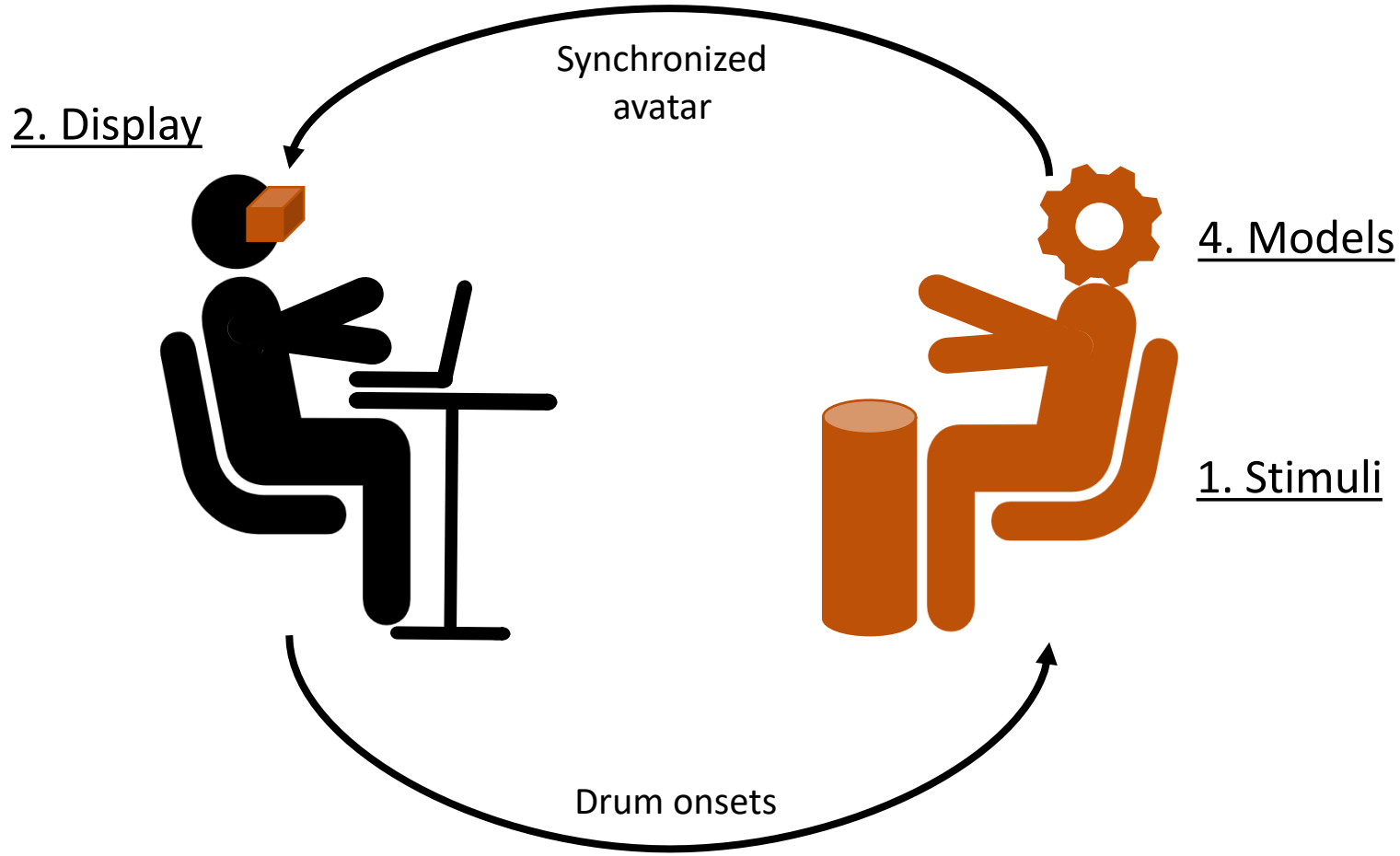
Head-mounted displays

Frameworks, SDKs, and APIs

- OpenXR
- Meta (Oculus Integration SDK)
- Microsoft (MRTK)

Streaming, building, deploying

- VR-ready GPUs
- Mac and Windows (+sideloading)


Synchronized
avatar
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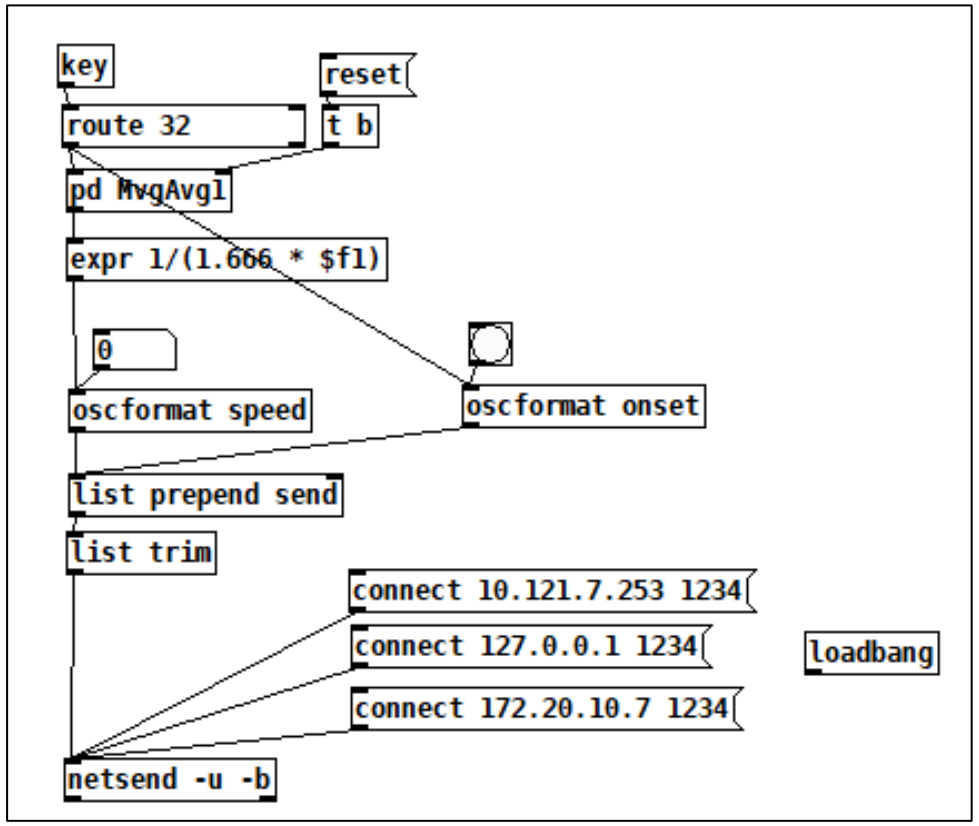
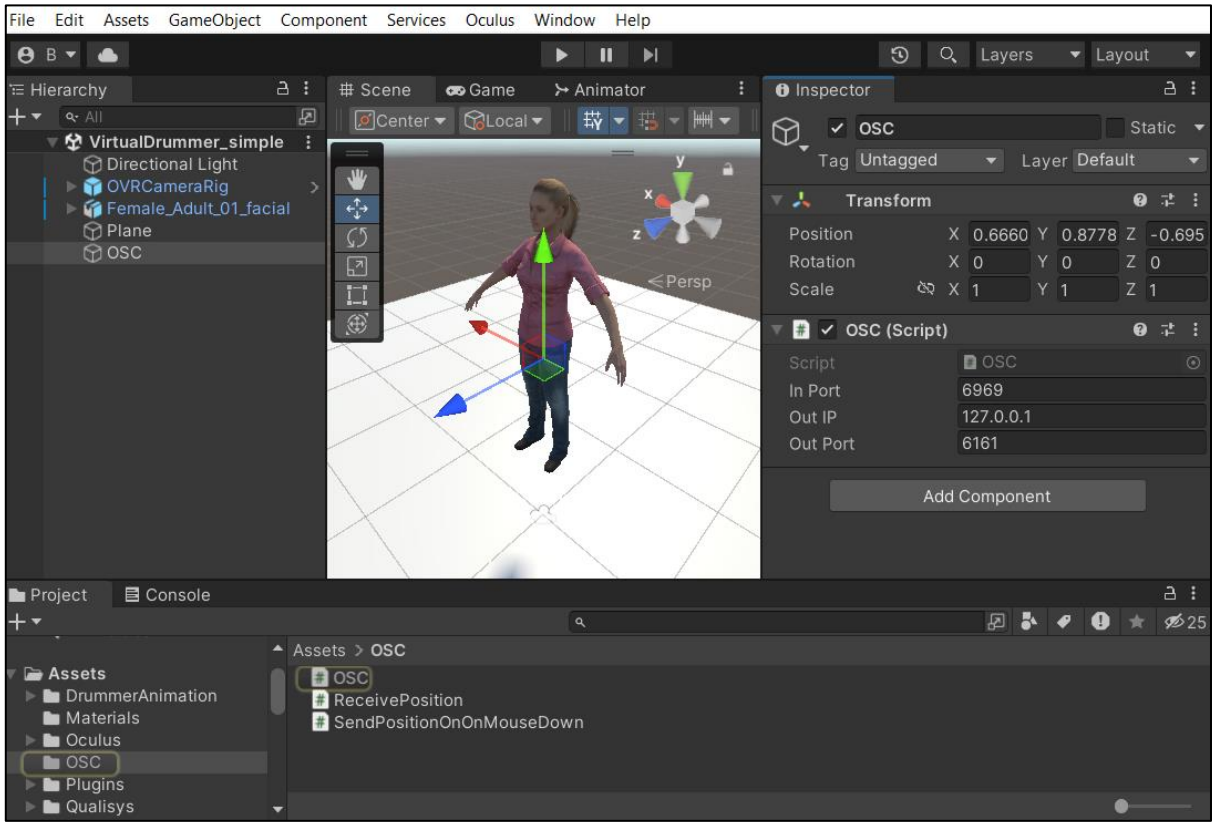
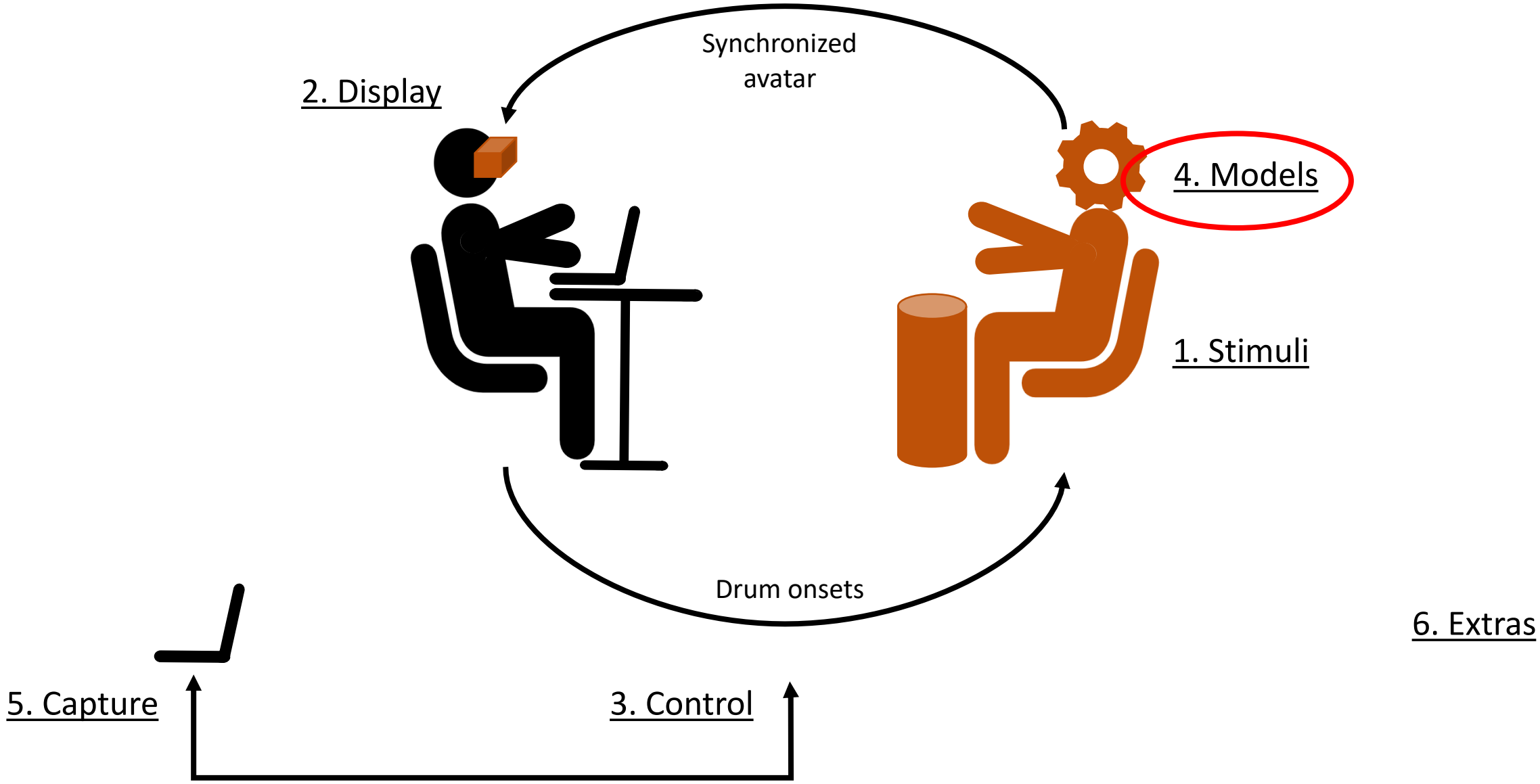
Networking


key
reset
route 32
t b
pd MvgAvg1
expr 1/(1.666 * $f1)
0
oscformat speed
oscformat onset
list prepend send
list trim
connect 10.121.7.253 1234
connect 127.0.0.1 1234
connect 172.20.10.7 1234
loadbang
netsend -u -b


File Edit Assets GameObject Component Services Oculus Window Help
Hierarchy
VirtualDrummer_simple
Directional Light
OVRCameraRig
Female_Adult_01_facial
Plane
OSC
Scene
Game
Animator
Inspector
OSC
Static
Tag Untagged
Layer Default
Transform
Position
Rotation
Scale
OSC (Script)
Script
In Port 6969
Out IP 127.0.0.1
Out Port 6161
Add Component
Project
Console
Assets
DrummerAnimation
Materials
Oculus
OSC
Plugins
Qualisys
Assets > OSC
OSC
ReceivePosition
SendPositionOnOnMouseDown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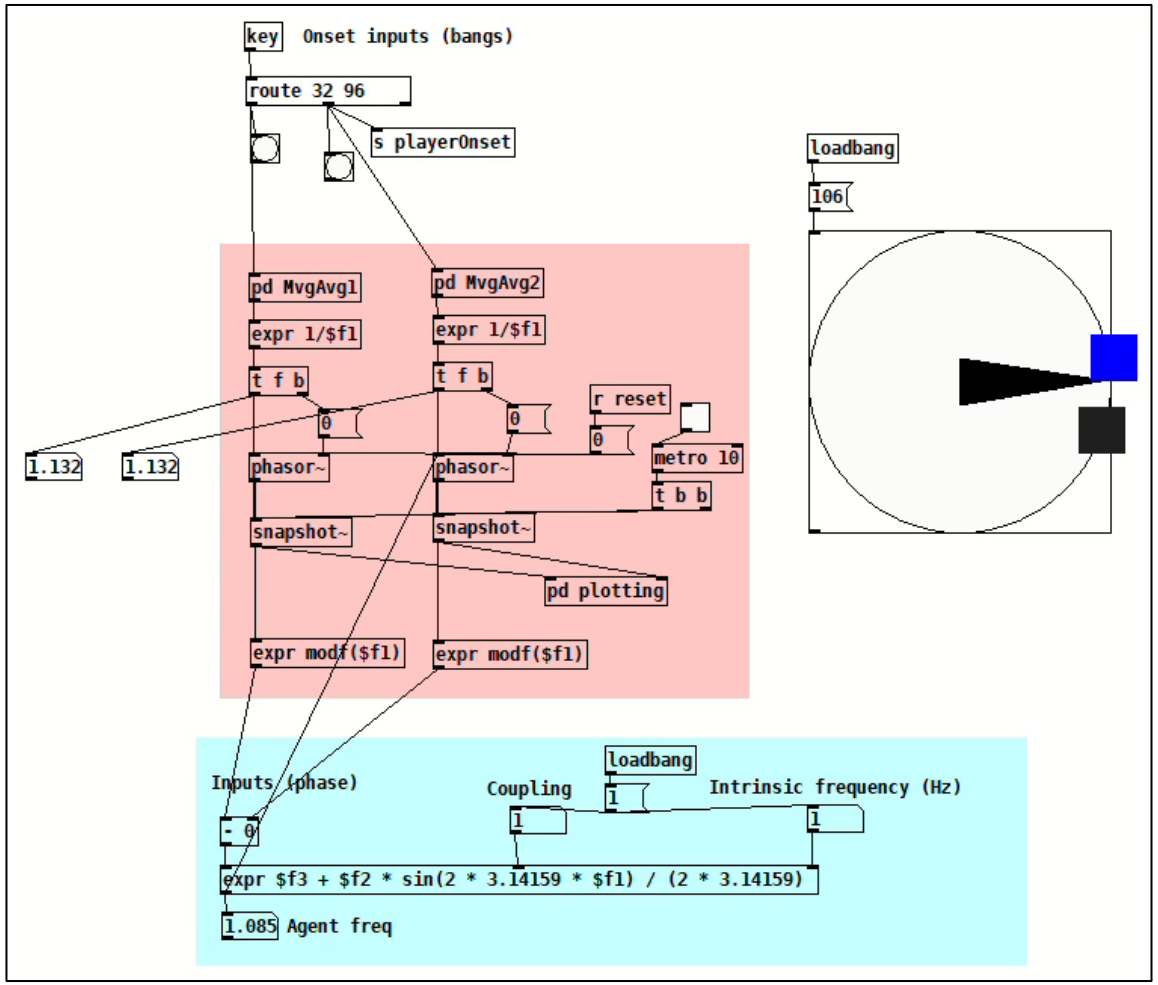
Oscillator models

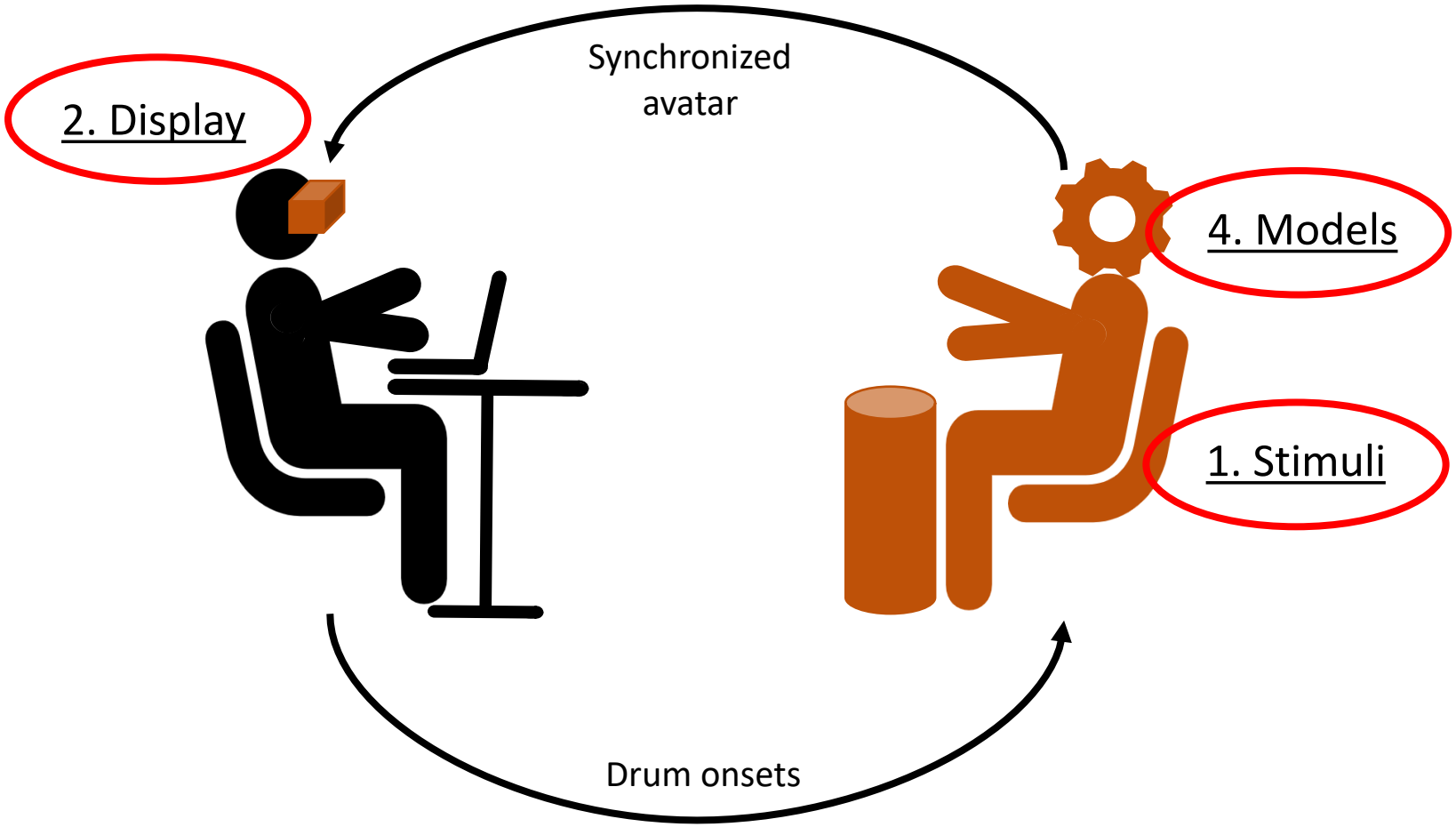
e.g. Kuramoto model

$$\frac{d\theta}{dt} = \omega_i + \frac{K}{N}\sum_{j=1}^{N} \sin(\theta_j - \theta_i), \qquad i = 1 \ldots N$$

+ variations and extensions



[Demos, Alexander P., et al. "Staying together: A bidirectional delay–coupled approach to joint action." Cognitive Science (2019)]
[Calabrese, Carmela, et al. "Modeling frequency reduction in human groups performing a joint oscillatory task." Frontiers in Psychology (2022]
[Tognoli, Emmanuelle, et al. "Coordination dynamics: a foundation for understanding social behavior." Frontiers in Human Neuroscience (2020)]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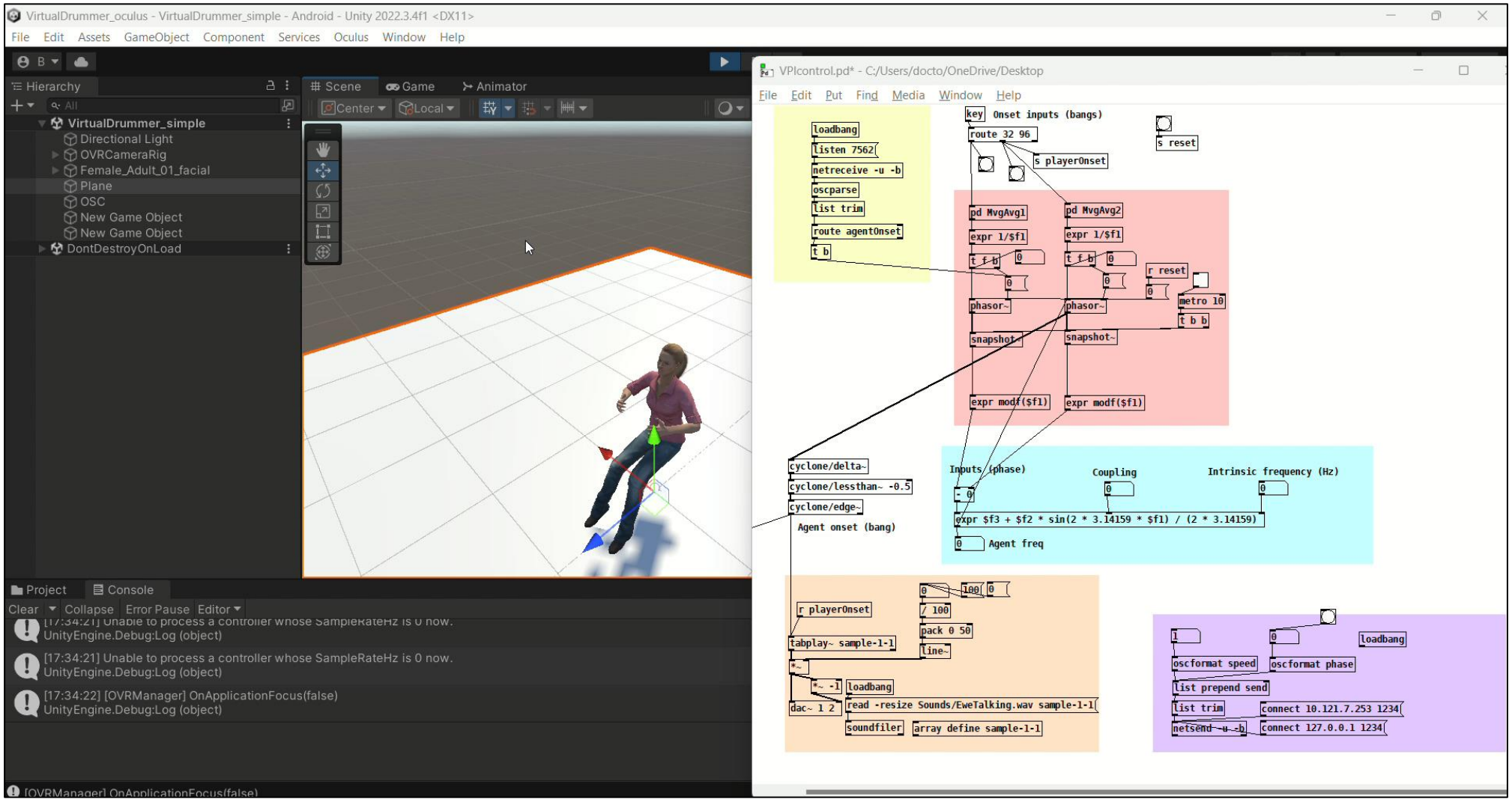
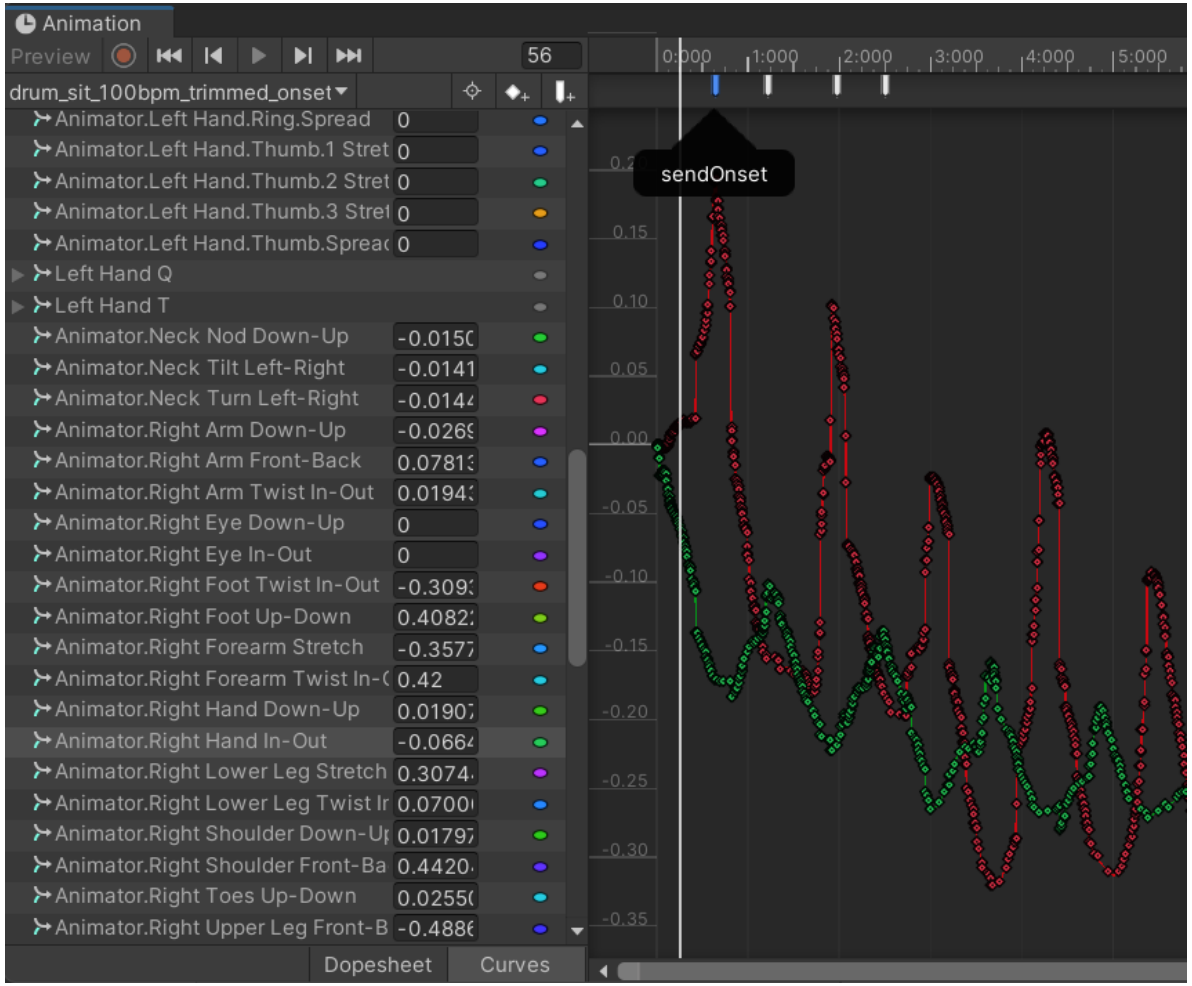

VirtualDrummer_oculus - VirtualDrummer_simple - Android - Unity 2022.3.4f1 <DX11>
File Edit Assets GameObject Component Services Oculus Window Help
Hierarchy
VirtualDrummer_simple
Directional Light
OVRCameraRig
Female_Adult_01_facial
Plane
OSC
New Game Object
New Game Object
DontDestroyOnLoad
Scene
Game
Animator
Center
Local
Project
Console
Clear
Collapse
Error Pause
Editor
[17:34:21] Unable to process a controller whose SampleRateHz is 0 now.
UnityEngine.Debug:Log (object)
[17:34:21] Unable to process a controller whose SampleRateHz is 0 now.
UnityEngine.Debug:Log (object)
[17:34:22] [OVRManager] OnApplicationFocus(false)
UnityEngine.Debug:Log (object)
[OVRManager] OnApplicationFocus(false)
VPIcontrol.pd* - C:/Users/docto/OneDrive/Desktop
File Edit Put Find Media Window Help
loadbang
listen 7562
netreceive -u -b
oscparse
list trim
route agentOnset
t b
key
Onset inputs (bangs)
route 32 96
s playerOnset
s reset
pd MvgAvg1
expr 1/$f1
t f b
phasor~
snapshot~
expr modf($f1)
pd MvgAvg2
expr 1/$f1
t f b
phasor~
snapshot~
expr modf($f1)
r reset
metro 10
t b b
cyclone/delta~
cyclone/lessthan~ -0.5
cyclone/edge~
Agent onset (bang)
Inputs (phase)
Coupling
Intrinsic frequency (Hz)
expr $f3 + $f2 * sin(2 * 3.14159 * $f1) / (2 * 3.14159)
Agent freq
r playerOnset
/ 100
pack 0 50
line~
tabplay~ sample-1-1
*~
*~ -1
loadbang
dac~ 1 2
read -resize Sounds/EweTalking.wav sample-1-1
soundfiler
array define sample-1-1
oscformat speed
oscformat phase
loadbang
list prepend send
list trim
connect 10.121.7.253 1234
netsend -u -b
connect 127.0.0.1 1234

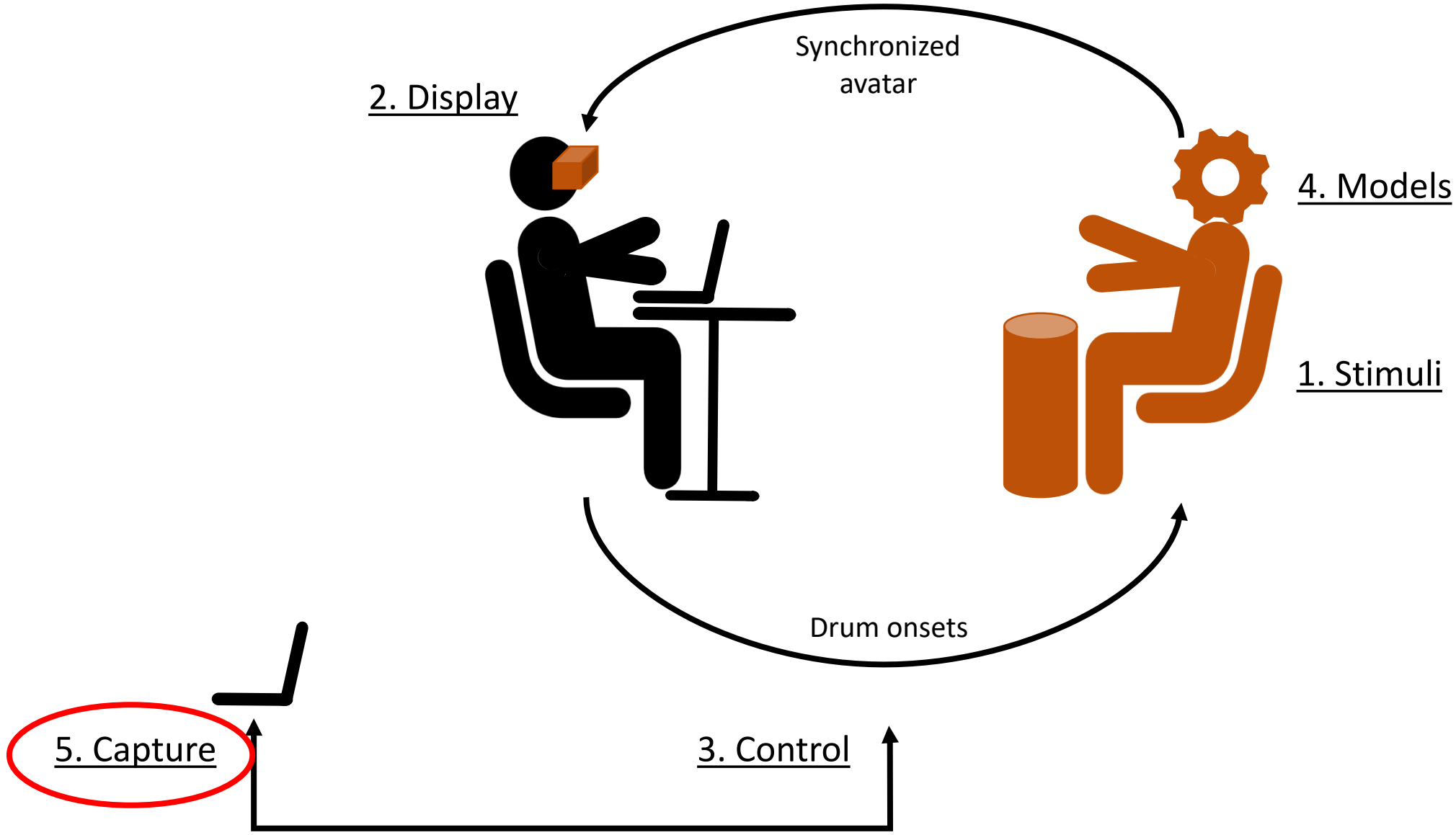
Latency and synchronization

- Pd → Unity
  - Single cycle animation
  - Multiple cycle animation
- Unity → Pd
  - Events in mocap timeseries

Latencies in …

drum pad, processing, (wireless) streaming to HMD, audio latencies

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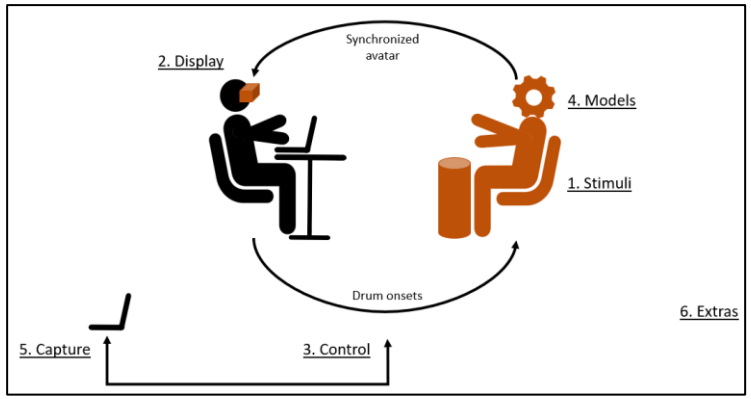
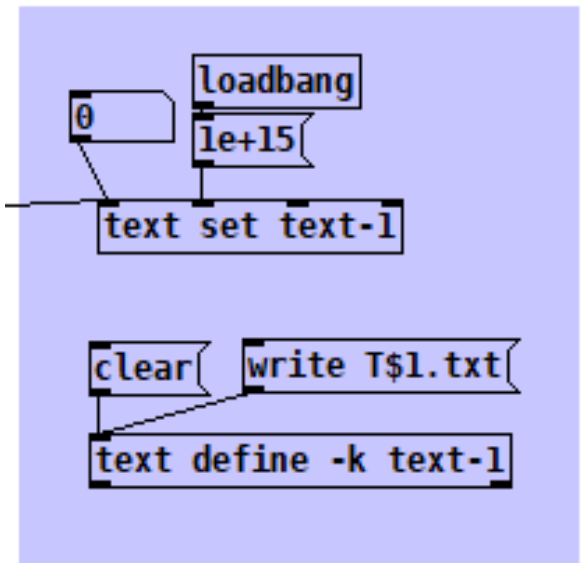




Assembly-CSharp | RecordData

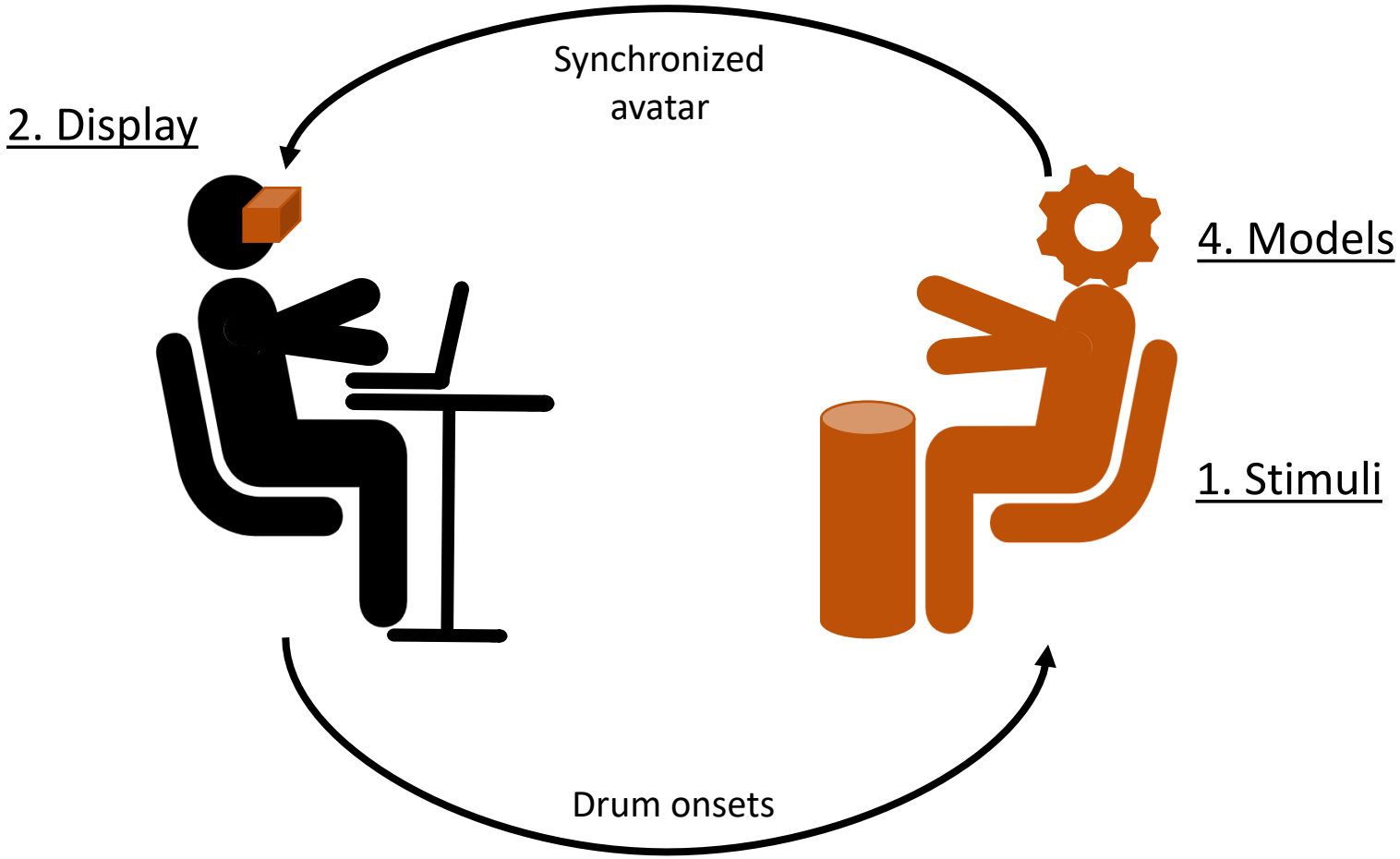
```
using System;
using System.Collections;
using System.Collections.Generic;
using System.IO;
using UnityEngine;

0 references
public static class RecordData
{
    private static StreamWriter _sw;
    private static string _path = string.Concat(Application.dataPath, "/../", "filename1.csv");
    private static string _header = string.Concat("trialname", Environment.NewLine);

    0 references
    public static void Initialize()
    {
        _sw = System.IO.File.CreateText(_path);
        _sw.Close();

        if (!File.Exists(_path))
        {
            _sw = System.IO.File.CreateText(_path);
            _sw.WriteLine(_header);
            _sw.Close();
        }
        else
        {
            System.IO.File.AppendAllText(_path, _header);
        }
    }

    0 references
    public static void LogOutput(string unityTime, float onset)
    {
        string _line2write = string.Concat(unityTime, ",", onset, Environment.NewLine);
        File.AppendAllText(_path, _line2write);
    }
}
```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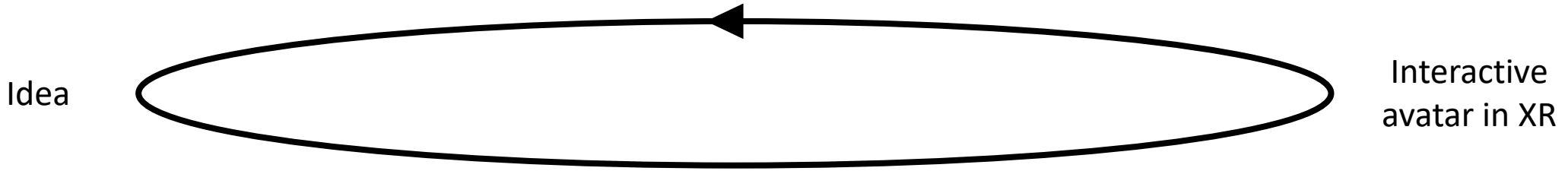
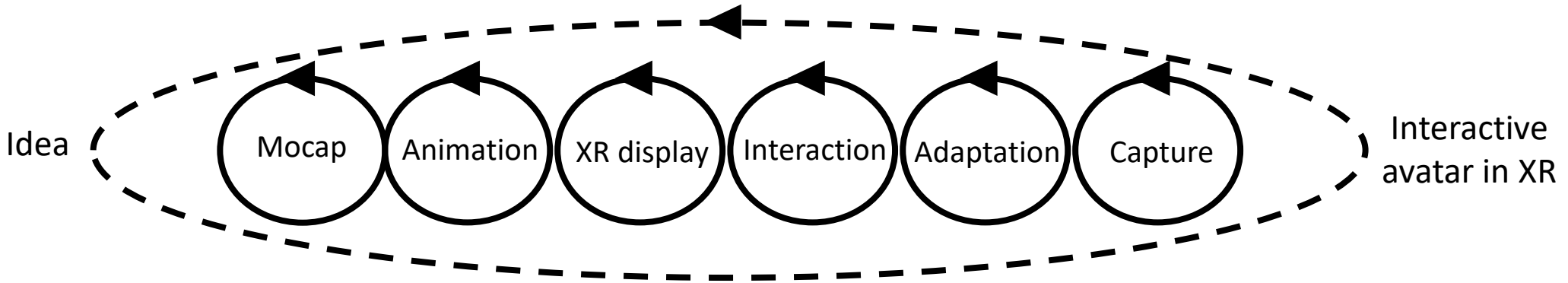
Iterate in short and rapid cycles





6. Extra

- Real-world alignment
- Multi-user
- Spatial/immersive audio
- Capture, (bio)feedback
  - (Neuro)physiology, eye gaze, action logs, …
- Use-cases?
  - Group dynamics [XXX]
  - Mirroring paradigms [XXX]
  - Body swapping [XXX]

www.github.com/bvk0/virtualDrummer

Questions, ideas, feedback?
Contact me on *LinkedIn* or *bavo.vankerrebroeck@mail.mcgill.ca*